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The Colorado River—The Southwest's Greatest Natural Resource

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It is apparent that the position of General Manager and Chief Engineer of the Dept. of Water and Power of the city of Los Angeles carries with it a great interest in the development of the Colorado River, because Los Angeles is a great beneficiary of its bounty. That this river is the Southwest's greatest natural resource there is no doubt; nor can it be doubted that the development—it can almost be said that the life—of that portion of the Southwest that is Nevada, Arizona, and southern California, is inextricably locked with that great natural resource. The effort will be to be factual, but if a partisan attitude creeps in, the reader's indulgence is asked.

Time was when the southwest United States was unimportant in population, industry and agriculture, but this appraisal can no longer fairly be made. With pardonable pride it is suggested that California is rapidly approaching the position of the second state of the union, and the city of Los Angeles the third city. Among metropolitan populations it was already third in the 1940 census. From the national standpoint, the accomplishments of the Southwest in the production of food, in the building of ships and aircraft, in the manufacture of countless war materiel during the recent great war are too well known to require demonstration, and it may fairly be said that much of this great war effort was made possible only by the forces—the water and the water power—of the Colorado River.

Yesterday, the Colorado River was a natural menace. Unharnessed, it tore through deserts, flooded fields, and ravaged villages. Its water was

drained from the mountains and plains, and rushed through sun-baked, thirsty lands, to be dumped into the Gulf of California, a treasure lost forever. Man, on the defensive, sat helplessly by, watching the river waste itself, or attempted in vain to halt the destruction left by its receding waters.

many and varied appliances that have made our civilization; it has turned the wheels of industry—and altogether is, now, a great constructive force. Only partly harnessed by Hoover Dam and other ingenious structures, the Colorado River is doing a gigantic job. It will yet do a greater one.

FIG. 1. The Colorado River Basin

Today, harnessed and controlled as it is, this mighty river is recognized as a great natural resource. It gives life to man and his efforts; it has made the desert bloom; it has enabled the production of countless tons of foodstuffs, which feed the world; it has brought light to houses that knew only the candle or the oil lamp; it runs the

Physiography of the Basin

The Green River rises in the snow-capped mountains of Wyoming; the Colorado River in the Rocky Mountains of north central Colorado (Fig. 1). These two rivers, and their tributaries, form the Colorado River system, and what is known as the Colo-

rado River flows nearly 1,400 miles in a general southwesterly direction, emptying into the Gulf of California, in Mexico. It is the second longest river in the United States, exceeded only by the Mississippi-Missouri system. It drains a vast area of 242,000 square miles in this country—one-twelfth of the area of the continental United States—and 2,000 square miles more in the Republic of Mexico. The basin is some 900 miles long and varies in width from about 300 miles in the upper section to 500 miles in the lower section.

The Colorado River system flows through or along the boundaries of seven large western states—Arizona, California, Colorado, Nevada, New Mexico, Utah and Wyoming—and into Mexico. Thus it is not only an interstate, but also an international, stream. The upper portions of the basin are mountainous plateaus, 5,000 to 8,000 ft. in altitude, marked by broad, rolling valleys, deep canyons and intersecting mountain ranges. The lower portion of the basin is characterized by broad, flat valleys, separated by low ranges, the greater portion being within what used to be called "the Great American Desert."

Climatologically, the Colorado River Basin has the extremes of year-round snow cover, with heavy precipitation on the high peaks of the Rockies, and desert conditions, with very little rain, in the areas of southern Arizona and the Imperial Valley in California. Extremes in temperature range from 50° F. below zero to 130°F. above. The entire basin is arid except in the extreme high altitudes of the headwater areas. Rainfall is insufficient for the profitable production of crops without irrigation. The growing season varies from about 80 days in the higher elevations of the mountainous section to the entire year in the low semitropical southern areas.

As this discussion is concerned with the resources of the river as they apply to the Southwest, the emphasis will be on what is known as the "lower basin."

History and Settlement of Lower Basin

Archaeological evidence indicates that the southern part of the basin was inhabited by ancient peoples—cave, cliff and mudhouse dwellers—eight to ten thousand years ago. Ruins of dwellings and storehouses, the remains of pottery, arrowheads and other artifacts scattered throughout the lower basin bear mute evidence of the existence of scattered Indian tribes, many of whom had disappeared before the coming of the white men. Farming by irrigation as now practiced in southern Arizona may be a modern revival of an ancient agricultural development, for some present canals have been found to follow closely the routes of ancient canal systems, and the valleys contain numerous ruins of the villages and storehouses used by peoples whose history is still in doubt.

The actual discovery of the Colorado River took place in 1540. Alarcón, Diaz and de Cardenas, three lieutenants of the great Coronado in his search for the "seven cities of Cibola," separately reached the river, sailed upon it for varying distances—one discovering the Grand Canyon—and explored a goodly portion of the lower basin. But it was more than 60 years later before that great stream was given a name.

In the winter of 1604–5—before the settlement of Jamestown and Plymouth —Don Juan de Onate, then the Gov-

ernor of New Mexico, made a trip from the upper reaches of the Rio Grande westward to what we know now as the Bill Williams River, and went down that river to its confluence with the Colorado, and thence down to the gulf. History credits Onate as the first to use the name Rio Colorado—doubtless derived from the red, muddy color of the stream.

The Americans began their explorations in the early 1800's, and in due course the whole basin was traversed.

The Treaty of Guadalupe-Hidalgo, signed in 1848 at the end of the war with Mexico, and the Gadsden Purchase in 1853 gave to the United States much of the territory now included in the seven basin states. When gold was discovered in California in 1848, the rush was on.

In the area around Yuma, Ariz., the river was being navigated in 1851; and, in fact, quite a trade existed with San Francisco. Gold seekers and other adventurers poured across the river at Yuma, and at Needles, some 200 miles north.

Lt. Ives, of the United States Army, in 1857, navigated the Colorado River to a point he called the "head of navigation," which is Black Canyon and now bridged by the mighty Hoover Dam. In his official report to the War Dept., he said (1, p. 48):

> The region last explored is, of course, altogether valueless. It can be approached only from the south, and after entering it, there is nothing to do but leave. Ours was the first, and doubtless will be the last, party of Whites to visit this profitless locality. It seems intended by nature that the Colorado River along the greater portion of its lone majestic way shall be forever unvisited and unmolested.

How wrong was Lt. Ives; how short his vision!

With the coming of the railroads, settlement of the Colorado River Basin slowly but steadily progressed, and in the lower basin the growth of population has far exceeded the wildest dreams of our forefathers. Mining, agriculture, stock raising—and finally industry—have brought a flood of people to the Southwest. From 1900 to 1940 the population of the United States increased about 75 per cent, but during that same period the population of the Colorado River Basin increased 250 per cent, and the population of those portions of Nevada, California and Arizona which lie within the lower basin increased 1,125 per cent (1, p. 50). The rise of war industries during the recent war has brought to the lower area of the Colorado River Basin its most rapid influx of people, particularly in Arizona, California and Nevada.

In 1913 Los Angeles, then a city of about 350,000 population, completed a great 240-mile aqueduct from the high Sierras in California. This increased supply of water, designed to insure the water supply for a city of 2,000,000 people, was the first great water development in southern California designed for a city's domestic needs. But what of the agricultural lands in the basin? As early as 1870, appropriations had been made to divert water from the Colorado River, in the Blythe area. By 1902 water flowed into the Imperial Valley of southern California, and a great agricultural area was born. Before 1930 the need for additional water for what is called the metropolitan area of southern California, which includes Los Angeles and neighboring communities, was apparent. Predicated upon the water and power of Hoover Dam, the great Metropolitan Water District Aqueduct

was locally financed and built, and in 1941 became operative. The waters of the Colorado River, pumped across mountain ranges and along and across desert sands, were then brought into southern California. Of this more later.

Development of River

For countless ages the Colorado River has gouged the rock of the mesas into gorges and chasms, the most spectacular of which is the world-famous Grand Canyon of Arizona—a titanic cleft, over 200 miles long, as much as 12 miles wide, and a mile deep. These processes of erosion will always continue. Rain and snow in abundance fall on the Rocky Mountains rimming the upper part of the Colorado River Basin, but great expanses in the lower areas are proportionately dry. The average annual precipitation of less than 15 in. for the entire drainage area is the lowest for the major river basins of America. Nearly 90 per cent of the moisture that falls within the basin returns again to the atmosphere through evaporation, and only about 10 per cent of the precipitation flows in the river channel. Yet this 10 per cent of the scanty precipitation on so vast an area makes up the flow of the Colorado (1, p. 55).

Before man built the existing structures providing partial river control, seasonal flow of the main stream and its tributaries fluctuated greatly. In the spring, the river, fed by melting snow, was a mighty, raging torrent, reaching flood peaks of 250,000 cfs. or more. Below the Grand Canyon section it overflowed its banks and inundated the country for miles around. In summer, in years of low runoff, its flow became a trickle by comparison, sometimes dropping to 2,500 cfs. (1, p. 56). The flow fluctuated greatly from year to year, and there was no stability to the agriculture that was dependent upon its waters. There were either great droughts which dried up the farm produce or terrible floods which drowned the land.

By September 1904, nearly 8,000 people had settled in the Imperial Valley of southern California; the river had been tapped; 700 miles of canal were in operation; 75,000 acres of land were cropped (1, p. 56). Levees had been built for the protection of the delta lands lying below the level of the river, each year to be lashed by silt-laden floods, which gradually built up the bed of the stream until it ran along an elevated course many feet above contiguous lands.

Levees were built higher and stronger, and maintenance was an expensive burden, complicated by international problems, as most of these levees had to be built in Mexico. Late spring, every year, forecast the tragic menace from floods—not, however, fully realized until 1905. Then the already raging Colorado River, swollen by flood waters from the Gila, broke through a cut that had been made four miles below the international boundary, and for 16 long months the Colorado River poured its entire flow over Imperial Valley's sunny fields and flourishing communities. The break was finally closed, with great difficulty and expense. About 30,000 acres of arable land had been inundated, many farms had been ruined, homes were destroyed, highways washed away and railroad tracks wrecked. Miles of mainline track of the Southern Pacific Railroad had to be moved to higher ground, and tangible damage in the millions of dollars was sustained (1, p. 58). The need of this region for

flood control was one prime motivating reason for the construction of Hoover Dam.

The Silt Problem

Silt has always presented and even now presents one of the greatest problems in the control of the lower Colorado River. In its natural state, the river carried a silt content exceeded by only one or two rivers in the world. Silt formed the Imperial Valley in the first place; then threatened to destroy it. Silt deposits, to a depth of more than 1,000 ft., dammed off the Imperial Valley from the Gulf of California and formed the huge basin existing there today. Silt had filled up the river bed, and raised the stream flow high above adjacent lands, necessitating higher and higher levees. Silt filled up the channels and diverted the river flow onto adjacent lands.

For some years before Hoover Dam was built, the average amount of silt being brought down the river was estimated at approximately 100,000 acre-ft. per year (1, p. 58). In February 1928, the Dept. of Agriculture fixed 138,000 acre-ft. as the total annual silt load of the river at Yuma (2). That Government bulletin further said:

FIG. 2. Hoover Dam

> While silt is the creator of much of the agricultural wealth of the lower Colorado River Basin it is also the greatest menace to irrigation development and water control. When irrigation water containing

silt is applied to fields the main portion of the silt is deposited near the upper end. From time to time the farmer is compelled to move the deposited silt to lower portions of the field in order to keep the land surface above the level of the irrigation ditch. It is estimated that the annual expense to the farmers of Imperial Valley on account of silt averages $2 per acre.

Tests of the water in the main canal of the Imperial Irrigation District prior to the building of Hoover Dam showed, on several occasions, a silt content of as much as 30 per cent by volume (3) which, contrary to common belief, is largely inert and without any fertilizing value. Thus not only the necessity of controlling the water but the necessity of controlling the silt were the major problems for many years. It was consideration of these problems that resulted in the 726-ft. height of Hoover Dam (Fig. 2). Lake Mead, as the reservoir has been named, has a storage capacity of approximately 32,000,000 acre-ft., but it has been estimated that if silt should continue to come down the river at its present rate, at the end of 100 years it would occupy more than one-third of that storage capacity (4). Only the construction of additional reservoirs along the upper river and in upper tributaries, with the consequent re-regulation of the stream, will cut down the amount of silt materially.

It is certain that agricultural development in the lower basin of the Colorado River system will endure no longer than silt is controlled. Many think that with the construction of Hoover Dam the future of agriculture has been secured; but the civilization on the lower Colorado River will pass, as did the civilizations on the Tigris and Euphrates Rivers, unless a permanent solution is found for the silt problem. In a sense, we are now at intermission time.

The struggle to control silt on the main stream and tributaries of the lower basin prior to the building of Hoover Dam was most difficult and costly. It has been eased for the present, although silt-free water released from Lake Mead picks up silt and moves it downstream, creating new problems of channel protection. A hundred years can pass very swiftly, however, and therefore study and investigation must continue, and more and more dams with desilting basins be constructed in the upper reaches of the river, if our civilization is to remain permanent. The normal erosion of 242,000 square miles of drainage cannot be materially lessened, and Man can only construct more and more works to store the silt.

Colorado River Compact

It has been mentioned that appropriations for the diversion of the water of the Colorado River were effective in the Blythe area as early as 1870. In the early 1890's appropriations were effective in the Imperial Valley area, and water was in use in the Imperial Valley in 1902. In 1923 the city of Los Angeles filed an appropriation. But other states had also been diverting water; each state in the Colorado River Basin had gone ahead with its own development without very much regard for the other states; and Mexico was also interested in this interstate-international river. By about 1918 it was apparent that diversions from the river had already become so great that the low water flow of the stream could not satisfy all appropriators.

The lower basin area, growing more rapidly in population than the upper

basin, was pressing for development of the lower river, and the upper basin had objected. The flow of the Colorado River was not stable, and it was not adequate to supply all of the uses envisioned by all of the states. And in low-flow years, such as 1924, when the flow at Lee Ferry dropped to less than 12,000,000 acre-ft., it was apparent that something had to be done. Proposals for storage in the lower basin were regarded by the upper basin states as threatening to establish priorities which would preclude later use of the water in the upper basin.

Laws respecting rights to the use of the waters of interstate streams were not well settled, each state claiming exclusively the right to regulate the appropriation of the waters within its boundaries; and the federal government claimed the right of jurisdiction over the stream because it had been navigable. It was argued that no reasonable regulation of the flow of the Colorado River by storage appeared to be feasible except with the approval and control of some authority higher than the states themselves, and that the federal government logically should effect the regulation of the Colorado River development. Obviously some form of an agreement between the various states was essential before comprehensive development of the river could proceed. A common desire for a solution gained momentum, and finally resulted in an interstate compact.

The Federal Constitution (Art. I, Sec. 10) provides that:

> No State shall without the consent of Congress . . . enter into any agreement or compact with another State. . . .

The document known as the Colorado River Compact was signed at Santa Fe, N.M., on Nov. 24, 1922, by commissioners from each of the seven basin states mentioned (5, p. 387). This action had been authorized by an act of Congress, approved Aug. 19, 1921 (42 Stat. 171); but while Congress had authorized the *making* of an interstate compact, under the Constitution, and the commissioners had signed, it still remained for each state to *ratify,* and for Congress to *approve* that compact.

As has been said, the hope was for an interstate division of the waters of the river, but this was not accomplished by the compact, which, so far as dividing the river was concerned, contented itself with a division between the upper basin and the lower basin. The compact fixed a basin division point at Lee Ferry, a few miles below the Arizona-Utah boundary; defined the upper basin as those parts of the states of Arizona, Colorado, New Mexico, Utah and Wyoming within and from which waters naturally drain into the Colorado River system above Lee Ferry, and also all parts of these states located without the drainage area of the Colorado River system which then were or thereafter should be beneficially served by waters diverted from the system, above Lee Ferry. The lower basin was defined as those parts of the states of Arizona, California, Nevada, New Mexico and Utah within and from which waters naturally drain into the Colorado River system below Lee Ferry, and also all parts of these states located without the drainage area of the Colorado River system which then were or should thereafter be beneficially served by waters diverted from the system below Lee Ferry. The upper division of the basin was defined as the states of

Colorado, New Mexico, Utah and Wyoming; the lower division, as the states of Arizona, California, and Nevada.

The commissioners who drafted the Colorado River Compact in 1922 dealt with the river on the assumption that its dependable flow was about 20,000,000 acre-ft. per year (5, p. 397). But in those days the period of record was short, and far drier periods have occurred subsequently.

The compact apportions in perpetuity to the upper basin states 7,500,000 acre-ft. per year, and to the lower basin states a like 7,500,000 acre-ft. per year. This is commonly known as "III(a) water," because that is the paragraph in the compact which apportions this 15,000,000 acre-ft. of water.

By paragraph III(b) of the compact, the lower basin states were given the right to increase their annual beneficial use by 1,000,000 acre-ft. California and Arizona are in dispute whether this III(b) water is "apportioned" water, Arizona contending that it is and California that it is not.

By paragraph III(c), provision was made for water to Mexico in the event of any subsequent treaty, and it was provided that such Mexican waters should be supplied from the waters which were surplus over and above the aggregate of the quantities specified in paragraphs III(a) and III(b)—that is, surplus above the 16,000,000 acre-ft. —with any deficit to be supplied equally by the upper and lower basins.

By paragraph III(d), the upper division states (Colorado, New Mexico, Utah and Wyoming) agreed that they would not cause the flow of the river at Lee Ferry to be depleted below an aggregate of 75,000,000 acre-ft. during any consecutive 10-year period, which is practically a guarantee that the flow at Lee Ferry will average 7,500,000 acre-ft. each year. There seems to be some doubt that even with large storage in the upper basin it will be able to use its apportionment of 7,500,000 acre-ft. per year and also meet its guarantee.

The compact provided that further equitable apportionment of the river system waters *unapportioned* by paragraphs III(a), III(b), and III(c) might be made after Oct. 1, 1963, if and when either basin shall have reached its total beneficial consumptive use specified in paragraphs III(a) and III(b) (the aggregate of 16,000,000 acre-ft.).

It is appropriate to discuss the recorded historical flow of the Colorado River. For the past 50 years the average flow of the river has approximated 17,720,000 acre-ft. at the international boundary, under assumed virgin conditions (1, p. 55). It is to be noted that within that 50-year period there have occurred 16 years when the flow has been much lower than the over-all average. For example, for the years 1930 to 1945, inclusive, the estimated virgin flow at Lee Ferry was an average of 13,500,000 acre-ft. per year, with some years running far lower—one only 5,500,000 acre-ft., and three less than 10,000,000 acre-ft. (1, p. 281). It is quite apparent, therefore, that even with large storage there is barely enough water on the average to permit satisfaction of the apportionments to the upper and lower basins as made by the compact, including the extra 1,000,000 acre-ft. to the lower basin, and of the obligations of the treaty with Mexico, especially if due consideration is given to losses such as those incidental to reservoir evapo-

ration, transpiration and channel percolation.

Each of the basin states has put its own construction and interpretation upon just what was meant by the compact, and Arizona and California specifically are in sharp conflict. Grave contentions exist, complicated as they are by the provisions of the Boulder Canyon Project Act and the requirements of the Mexican Treaty—and the disputes are exaggerated, if you please, by the current low flow in the last 17 years of drought.

The upper basin states have been struggling for some time to agree upon a subcompact between themselves in order to determine their individual rights, but as yet the answer has not been found.

The lower basin states seem to be unable to settle their individual contentions by subcompact or arbitration, and are in hopeless conflict.

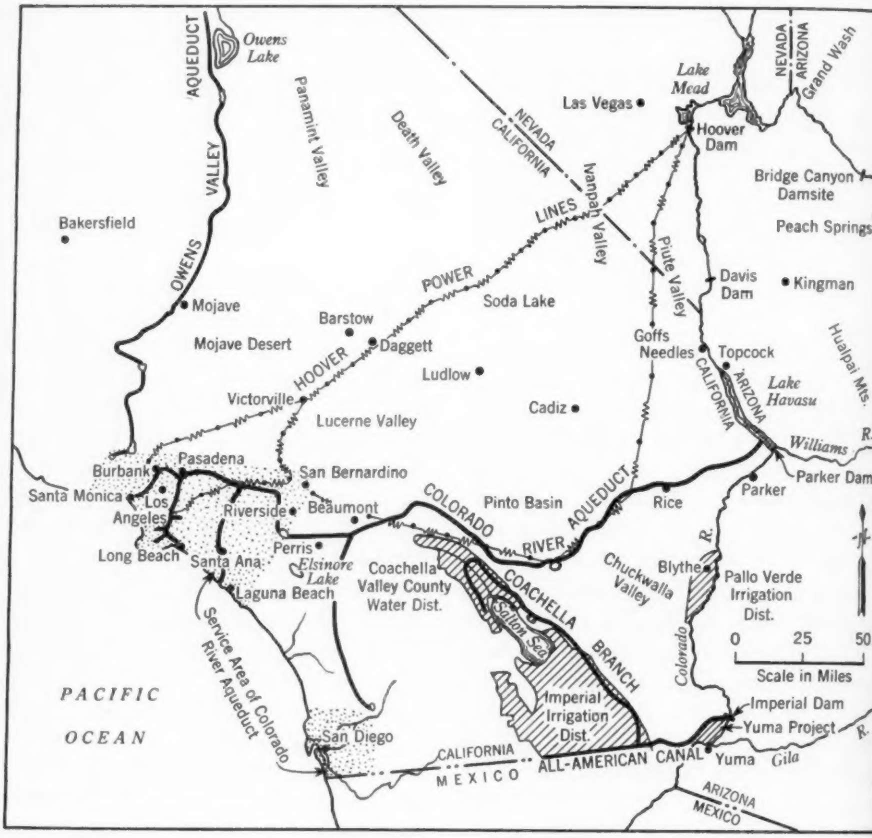

Fig. 3. Aqueducts and Transmission Lines

Building of Hoover Dam

Congress was not unresponsive to the contentious situation on the river, for in 1920 it passed the Kincaid Act (approved May 18, 1920), which directed a report on the river. On Feb. 28, 1922, what is known as the "Fall-

Davis" report was presented and was printed as a Senate Document (6). Extensive hearings were held by both the Senate and House Committees on Irrigation and Reclamation, and other reports of engineering boards and of the Dept. of the Interior were made over a period of years, assisting in developing full and accurate information.

From 1919 for nine long years, the efforts continued, with California in the front, seeking control of the floods and the silt, the impounding of the waters to insure year-round use, and the generation of hydroelectric power —all of which were needed desperately.

Finally, the fourth Swing-Johnson bill was introduced in 1927. This was the bill, with various amendments, finally approved on Dec. 21, 1928 (45 Stat. 1057), known as the Boulder Canyon Project Act, which authorized the construction of the great dam at Black Canyon, now known as Hoover Dam, the construction of the All-American Canal, and other works; and the great dream appeared near accomplishment (Fig. 3).

The Project Act is a long and complicated document, and only a few of its important provisions can be mentioned. It directed the Secretary of the Interior to obtain contracts which would provide revenues from power and domestic water sales sufficient to repay the complete cost of the dam together with interest to the federal government at 4 per cent per annum, before any construction was commenced, so that the project would be "a self-supporting and financially solvent undertaking."

Southern California contractors, including the Dept. of Water and Power of Los Angeles, did enter into firm contracts with the federal government guaranteeing to take all of the power generated at Hoover Dam at rates sufficient to reimburse the government's expenditures fully, plus interest. The big job was started and finished. Thus did the principles of economic feasibility and of full reimbursability come to full flower, and Hoover Dam and its appurtenant works remain the standard of such principles.

The act also authorized the Secretary of the Interior to contract for the storage of water in the reservoir behind Hoover Dam and for the delivery thereof at such points on the river as may be agreed upon, all subject to the Colorado River Compact.

Fearing the development of southern California—a development that has actually occurred—senators from other states of the basin were able to insert in the act (Sec. 4a), as a condition precedent to its effectiveness, a requirement that California, by act of its legislature, and for the benefit of the other states in the basin, agree irrevocably and unconditionally with the United States to limit its annual consumptive use of the water from the river. California, by act of its legislature, did so limit itself, this act being commonly known as the "California Limitation Act" (7). But notwithstanding the good intentions of all parties, this provision of the project act and the resulting self-limitation by California is the subject of a bitter controversy with Arizona. The meanings in this limitation and the compact are still being quarreled over by lawyers and engineers, and implications are so complex as to preclude any extended discussion.

At the time the project act was being considered, six of the basin states had ratified the compact, more or less

conditionally, but Arizona had refused to do so. The act therefore required ratification by only six states, and the compact was approved on that basis.

Certain provisions of the project act of 1928 were amended by the Boulder Canyon Project Adjustment Act of 1940 (54 Stat. 774), but these amendments did not affect the general controversy.

Water Contracts

Under the authority of the Boulder Canyon Project Act of 1928, and beginning in 1930, the Secretary of the Interior entered into contracts with five California agencies: the Metropolitan Water District of Southern California, the city of San Diego, the Palo Verde Irrigation District, the Coachella Valley County Water District and the Imperial Irrigation District, calling for an aggregate delivery of 5,362,000 acre-ft. of Lake Mead water annually for use in California. The California agencies contend that these contracts are a confirmation of and definitely fix the amount of water legally usable in California within the project act and the limitation act, but Arizona contends that the contracts' aggregate is in excess of the water which California may lawfully use under those acts.

Nevada has secured its contract for 300,000 acre-ft. annually of Lake Mead water, and when Arizona ratified the compact, in 1944, it secured from the Secretary of the Interior a water delivery contract calling for 2,800,000 acre-ft. of Lake Mead water annually, plus one-half of the excess or surplus. California contends that Arizona is not entitled to such a withdrawal, because the flow of the Gila River, a tributary of the Colorado River, and obviously a part of the river "system," is consumptively used by Arizona to a total of about 2,300,000 acre-ft. annually (1, p. 285), and that Arizona's "take" from the main stream must be charged with its consumptive use of Gila River water.

It should be recalled that the compact apportioned to the lower basin 7,500,000 acre-ft. of water annually, with the right to increase that use by 1,000,000 acre-ft., and that the aggregate water deliveries called for by the contracts made by the Secretary of the Interior with Arizona, California and Nevada are 8,462,000 acre-ft. None of these contracts cover Gila River water, which California engineers estimate is consumptively used by Arizona to a total of 2,300,000 acre-ft. The Gila River is undoubtedly a part of the Colorado River System, and hence it appears that the aggregate of the contracts—8,462,000 acre-ft.—plus the Gila use total 10,762,000 acre-ft., which is certainly more than the compact allots to the lower basin, however it is construed. This is the basis of one of the bitterest quarrels between Arizona and California.

Metropolitan Water District

As has been indicated, the growth of Los Angeles in the first three decades of the Twentieth Century had justified the building of the Owens River Aqueduct. Thus water was brought down approximately 240 miles from the high Sierras, at a cost now of approximately $90,000,000—because this water, together with the resources of the Los Angeles River Basin, was believed to be sufficient to serve a population of about 2,000,000 people. And still there was a demand for additional water. All available sources (available in the sense of economic and engineering feasibility) had been tapped, and, co-

incidental with the efforts to secure the building of Hoover Dam, the city of Los Angeles had investigated the possibility of diverting additional water from the Colorado River, and, in 1924, had actually filed an appropriation therefor. As this idea grew, with its attendant cost, the scheme calling for the creation of a metropolitan water district came into being.

The Metropolitan Water District of Southern California is a public agency, created by California statute (8), and overlies the city of Los Angeles and 14 other communities of southern California, including the recently added San Diego County Water Authority. It supplements the water service to some 2,350 square miles in the southern California littoral, with a potential population of 9 to 10 million people. The communities composing the Metropolitan Water District of Southern California, on Sept. 29, 1931, authorized a $220,000,000 bond issue for the purpose of building the Metropolitan Aqueduct from Parker Dam to the coastal communities of southern California, including the city of Los Angeles; and these bonds constitute a mortgage against every piece of taxable property within this Metropolitan Water District area. Construction of the aqueduct started in 1933, the job being finished and the aqueduct becoming operative in 1941.

In 1930 the Metropolitan Water District of Southern California received a contract, which, with a supplemental contract made in 1931, and that covering the San Diego area, now provides for the delivery by the government of 1,212,000 acre-ft. of Lake Mead water per year. Water has been flowing through the aqueduct since 1941, and serving the communities within the district, the population of which is more than 3,000,000 people at present. Not all of the water to which the Metropolitan Water District is entitled by its contract is being diverted from the river; but, of course, communities must lay plans for their water supplies against the foreseeable future. Irrespective of the desires of individuals about the size of the community in which they wish to live, there seems to be no way to stop the growth of southern California except to draw the cord of water shortage around its neck. Water in this area—for domestic use, for irrigation and for industry—is indeed life.

The Metropolitan Aqueduct is an example of the permitted use of the Colorado River outside of the natural drainage area, and the Metropolitan Water District of Southern California, by the terms of the compact (Art. II(g)), has become a part of the lower basin. The aqueduct stands as a great example of a permitted trans-mountain diversion, bringing needed water to a great metropolis not built upon the river. Other trans-mountain diversions have been planned, and some are approaching completion. The Moffatt Tunnel and the Colorado–Big Thompson projects in Colorado are typical. There are others, such as the Colorado-Arkansas, the Provo and the San Pete proposals; and, needless to say, areas contiguous to the river view with considerable alarm the development of the trans-mountain diversion idea. The facts emphasize the problems that must be faced, because great communities need water, whatever the cost. The people of our modern cities must be served.

Mexican Treaty

Although the Boulder Canyon Project Act provided in its enacting clause

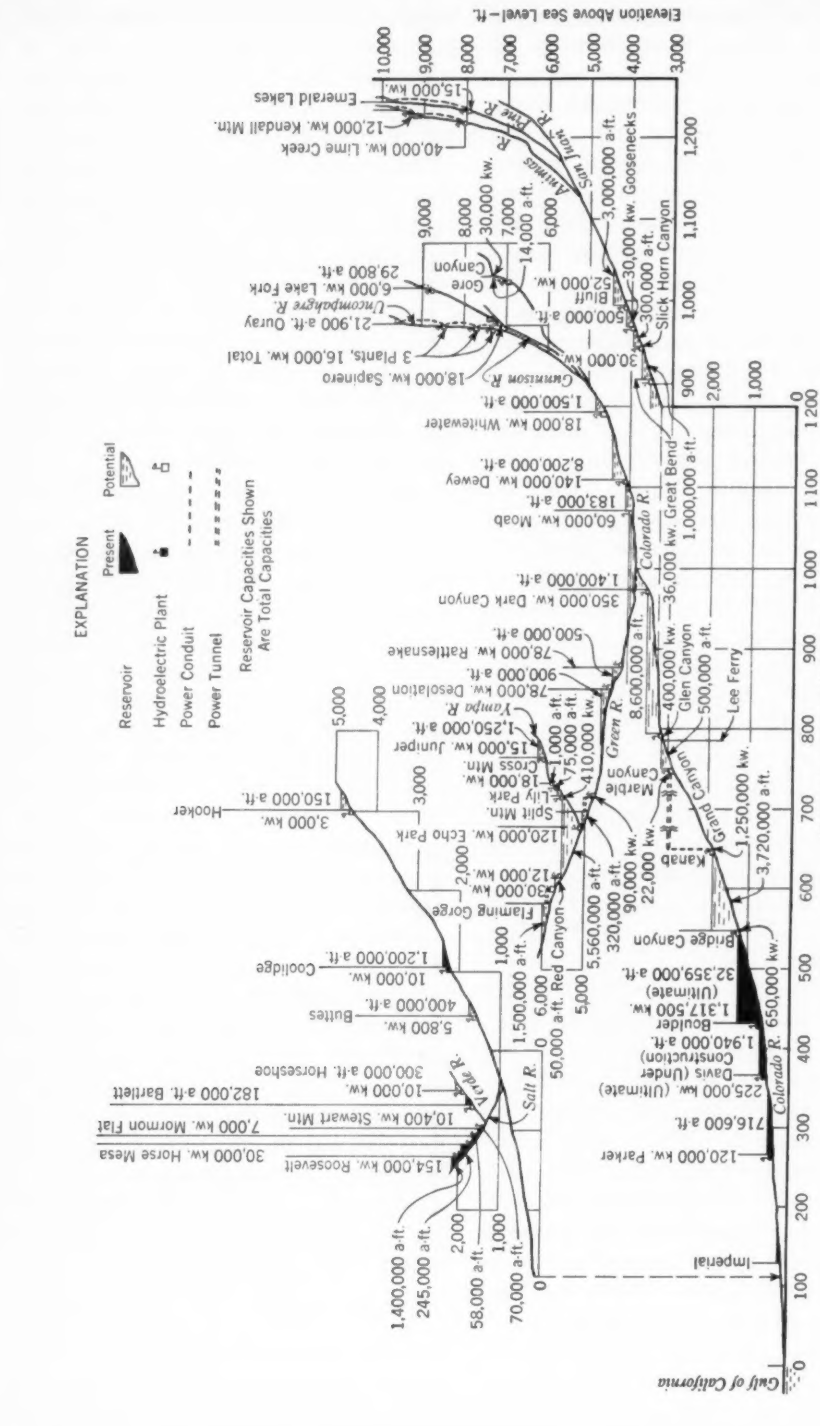

Fig. 4. River Profile, Reservoirs and Power Plants

that the dam authorized thereby was to be constructed "for the delivery of the stored waters thereof for reclamation of public lands and other beneficial uses within the United States," as well as for other purposes, the government also recognized the possibility of a treaty with Mexico concerning the waters, for the project act declared (Sec. 20):

> Nothing in this Act shall be construed as a denial or recognition of any rights, if any, in Mexico to the use of the waters of the Colorado River System.

For about 130 miles, the river flows through Mexican territory before spilling into the Gulf of California, and for many years diversions from the river have furnished irrigation waters to Mexican lands. Consumptive use of such waters has been estimated at about 750,000 acre-ft. annually, but even this was sporadic, and certainly indefinite, due to the variations in the river's flow from season to season and from year to year.

It became obvious, as time went on, that Mexico's rights in the river had to be recognized definitely; and, without going into the political and economic background of this action, it will be noted that in 1945 the Senate of the United States ratified a treaty between the United States of America and the United Mexican States, whereby Mexico was allotted a firm draft on the river of 1,500,000 acre-ft. per year (1, p. 66). This, California contends, is more than twice the amount of water that Mexico had ever beneficially used, and it is certain that the draft on the river permitted by this Mexican Treaty has drastically thrown the water budget of the river out of balance. For the past 17 years a drought has existed in the Colorado River Basin, with resultant low flow, and today the water stored behind Hoover Dam is about 60 per cent of its capacity. The treaty is a fact, and allocates the first draft on the river. The basin states must recognize that fact.

Hydroelectric Power

It has been well said that "a prerequisite for industrial growth in any area is the availability of a sufficient amount of low-cost electric power," for certainly the southern California littoral has proved both the principle and the result. Specifically, it may not be denied that the Dept. of Water and Power of Los Angeles, in the generation of low-cost hydroelectric and steam power on its own behalf (of which it is now furnishing over 1.5 billion kwhr. annually), and in the transmission of power, more than half of which is generated by falling water in the Colorado River, has made available to its distribution area tremendous benefits. The people, in their homes and farms and industry, have attained a wealth of the amenities of a standard of civilization not exceeded in the world. And the story is not finished; the book has not been closed. This is not a report of the Dept. of Water and Power, but the story of the Colorado River; and other agencies, public and private, are distributing power from the river. The blessings from the control of the river cannot be counted without including its present, and its potential, production of hydroelectric power (Fig. 4).

Hoover Dam was built, and is being paid for, through the contracts required by the project act to be made by the Secretary of the Interior before a shovel of earth was turned. These contracts with southern California agencies call for the sale and purchase of the power to be generated at the dam at rates sufficient to amortize and pay

off the full cost of construction and all operation and maintenance. The power plant—the largest in the world under one roof—is designed for 17 generators, with an installed capacity of 1,317,000 kw., of which 13 are now installed, with a capacity of 1,030,000 kw., able to generate more than 4.5 billion kwhr. annually. Practically all of this great flow of power was used in southern California and the tributary area of southern Nevada during the war years, with the city of Los Angeles and its neighboring cities of Burbank, Glendale and Pasadena using nearly 50 per cent of that total output. This power had a salutary effect upon our war effort, which, to their discomfort, Germany and Japan well know.

But the load in southern California has continued to grow since the end of hostilities, due to the location of new industries, the expansion of old, and the constant influx of new population. It has been estimated that Los Angeles, alone, is increasing in population by about 80,000 people annually; and great increases are noted all over the Southwest. People are pouring in; new industries are being located; and old ones are hard put to meet increasing demands upon them.

Parker Dam, behind which the waters of Lake Havasu are impounded and from which the Metropolitan Aqueduct draws its water, has an installed capacity of 120,000 kw., producing 500 million kwhr. annually, and all of this power is used. Davis Dam, now under construction about 70 miles downstream from Hoover, is designed to generate 225,000 kw. and to furnish 800 million kwhr. annually—an amount inadequate to meet the current demand. Not only does Los Angeles need more power, but so does the rest of southern California, and Nevada and Arizona. Currently, southern California alone is constructing 750,000 kw. of steam capacity. A vast reservoir of potential hydroelectric power still exists in the lower Colorado (below Lee Ferry), awaiting development. The Bureau of Reclamation has estimated in its "comprehensive report" that development of potential projects in the lower basin could make an additional 2 million kw. available, producing over 10 billion firm kwhr. That this additional power is needed can be readily seen, for the bureau also estimates that by 1960 the demand for power in the lower basin will exceed the output from all existing, all authorized and all potential projects on the river (1, p. 15). It is appropriate to suggest that the lower basin states, in ratifying the Colorado River Compact and apportioning 7.5 million acre-ft. annually to the upper basin states, confirmed the diversion of more than 40 per cent of the potential power on the lower river. Early construction of some of these potential plants is urgently needed to avoid a power shortage and the resultant curtailment of economic development.

But even so, the economics of these potential plants must not be overlooked. Government properly should build them, but power should pay its way; and, with reasonable rates, fully reimburse with interest all governmental expenditures for the power alone. It is not intimated that power should not, in some degree, subsidize other beneficial uses of water, because one dam can not only provide the means for producing power but can also further regulate the stream by impounding water, thus making possible an extended use and control of and diversion from the river. But the cost load on power should be no greater than if the dam were built for

power alone, with only the "unearned increment" utilized for the development of needed and economically feasible water projects.

A recognition of the principles of reimbursability present in the Hoover Dam project will keep future projects out of trouble, and will continue to make possible the generation of low-cost power so gravely needed for the great Southwest. For example, the Dept. of Water and Power is now studying a great and strictly power project which contemplates the construction by the government of a great dam at Bridge Canyon, with supplemental storage at Glen Canyon, at an estimated cost of $380,000,000. The capacity of this plant is to be 880,000 kw., and it will generate 3.5 billion kwhr. annually. The plan is for this project to be fully reimbursable and repay to the government every cent of reimbursable cost, with interest, and within a reasonable period of time. This project, a single-purpose power project, is not designed to divert any water for irrigation or other consumptive use. It will bring low-cost power into this area, where it is so badly needed—where, in fact, it has been estimated that the total output will be absorbed within a decade. Such a project would not only be a real contribution to the Los Angeles area and the whole Southwest, but would be of incalculable benefit to the solutions of still-existing problems on the river, such as re-regulation and flood and silt control.

How different is this contemplated project from the multiple-purpose project currently proposed for "Central Arizona" (9), where the estimated cost is over a billion dollars, where only large power subsidies and the diversion of power interest to repayment of irrigation capital costs can make possible the irrigation features, where even then the load against irrigated acreage is staggering, and where the water proposed for diversion is claimed by California as a part of its rightful share of the river.

Nothing said should be taken as indicating any attitude by California that the full power potentialities of the river should not be developed. On the contrary, full development is urged —but on economically feasible bases. Maintenance of the standards of feasibility that have brought domestic, agricultural and industrial health to the lusty young giant that is the Southwest should not be abandoned. The job is not yet done.

Government Interest in the River

No one can fairly deny that when in 1902 the Congress enacted the first reclamation law a great impetus was given the arid Southwest. The law was not specifically designed to aid the Southwest alone but "for the reclamation of arid and semiarid lands" in 16 western states and territories, including the seven basin states of the Colorado River system. The reclamation law of 1902 (10), with its amendments over the subsequent years, has afforded tremendous benefits to all of the western states, and particularly to those of the Southwest. Under the operation of those laws, the great Salt River Valley—Central Arizona—has developed and been made into one of the greatest agricultural areas in the country; Imperial Valley, in southern California, has become a great garden spot—a veritable oasis in the Great American Desert. Who can deny the blessings that are the water and the power from the controlled Colorado River? And yet the river is no genie

of the lamp, with inexhaustible resources. The river is only as valuable as its dependable flow, which is not the same as its variable high waters. The river can be overdrawn, and much of the civilization dependent upon it can revert to desert, unless the judgment of economics extends beyond political considerations.

The Bureau of Reclamation, in 1946, issued what is called a "comprehensive report" on the river (1), which lists not only existing and authorized projects but also an additional 134 potential projects. The report also shows that to put to use these 134 potential projects will, at 1946 prices, cost some 3.5 billion dollars (1, p. 5) and cause an overdraft of 25 per cent against the dependable flow of the river (1, p. 14). In other words, the report is a listing of projects from which a plan may be developed.

Of course it is natural that each state, each area with a potential from the river's bounty, will desire that it be served. Who can say which of the 134 projects shall be developed, which shall not? What standards shall so determine? The existing laws of the nation fix certain standards of feasibility for reclamation projects, and require that they be built with due regard to the engineering and economic factors involved, and that they pay out within a reasonable period of years, at a cost that can be met.

Hoover Dam *will* pay out—every dollar, with interest—and in a reasonable period of time. But now proposals are being made for multiple-purpose projects to cost hundreds of millions of dollars, the irrigation features payable only through increasingly heavy subsidies from the power users, over long periods of time, such as "the life of the project"—eighty years and longer—and these irrigation allocations will not bear interest. Given enough time, with no interest, and minimum amortizations, any project can pay out. Can this be the standard for such projects? Power allocations carry a current annual interest rate of 3 per cent; those for irrigation carry no interest. No complaint is made against this practice, but it should be recognized that an interest rate of even 2 per cent annually would amount to 160 per cent of the irrigation cost allocation in an 80-year period of repayment.

The principles of full reimbursability evidenced in the Hoover Dam project can still afford the basis for initiating additional projects which will meet the increasing need for power, when the need exists. We should not await a depression to build such necessary projects. They should be singled out; and the government can well go ahead with economically sound—and needed—projects, and thus continue its reliability as the source of power and other benefits on a government-controlled, interstate-international river.

Reclamation projects—with power facilities—should be considered as any other investment would be. Standards of economic feasibility, proved sound, should be the standards of future projects, which should be reimbursable within acceptable economic limits. Political boondoggling and logrolling should not be permitted to gamble with so great a national resource.

Government, itself, will reap tremendous benefits from the increased industrial activity; from the resulting increases in the tax base; from the impregnability of our national defense; and, more important, from the increased standards of civilization in which the whole country will benefit.

But consideration must be given to avoiding the "ratholes" which have the tendency to drain our plenty into poverty. Projects are being proposed by which a settler will be called upon to obligate himself for $50,000—yes, and $70,000—to pay out his 160-acre farm (11). Reclamation projects are being proposed which are estimated to cost as much as $2,000 per acre, to be paid for by the settler (9), while nearby land, already under irrigation, can be purchased for much, much less. This does not seem to be good business.

Power can pay only so much; cheap power is a blessing; expensive power, a burden. Projects are being considered in which the subsidy to irrigation from power is believed to be so high that power users will generate their own power. Water power is a blessing; it conserves our natural coal, gas and oil resources—all most desirable objectives. But there is a limit. No multiple-purpose project on the Colorado River should have allocations of cost loaded against power to a greater extent than if the project were for the single purpose of power. In such a manner only can our people afford the blessings of hydroelectric power. Blessings too expensive to enjoy are as "sounding brass and a tinkling cymbal."

Quarrel in Lower Basin

Now a brief word about the Arizona-California controversy. California and five other basin states made various ratifications of the compact, but Arizona did not. Its central area was rapidly developing, and the Salt River Valley was becoming an important agricultural production center. The Gila River, rising in New Mexico, flowed across the whole state of Arizona and emptied into the Colorado River above Yuma. The Gila River was and is an important tributary of the Colorado, and its waters had been appropriated and were in use at the time the compact was signed. Because the compact dealt with "system waters," and Arizona claimed the exclusive use of the Gila, which flowed within the lower basin, Arizona refused to ratify the compact. Arizona fought against the project act, and was a potent factor in requiring the California Limitation Act as a prerequisite to the effectiveness of the project act, and the building of Hoover Dam.

After the project act was on the books, Arizona contended that it was unconstitutional, and, in 1930, filed its first action in the Supreme Court of the United States, against the Secretary of the Interior and the other six basin states, seeking an injunction against the enforcement of the compact, the act, and contracts under the act for the diversion of water stored behind the dam (*Arizona* v. *California*, 283 U.S. 423). The decision by the Supreme Court, filed May 18, 1931, held the act to be within the power of Congress and constitutional; held that the river was navigable and that the authority to build the dam was a valid exercise of Congressional authority; held that no actual impairments, but only potential invasions, of Arizona's rights were threatened; and that because Arizona had not ratified the compact it was not bound thereby.

So the government proceeded under the project act to build the dam and appurtenant works, and made contracts with water and power users in California. Power contractors of southern California, including the Dept. of Water and Power, guaranteed to take the power generated at the dam at rates calculated to repay the cost of

the dam completely in 50 years. The power contractors also obligated themselves for the construction of the necessary transmission lines and appurtenant works, including the generative equipment in the dam itself. The Metropolitan Water District of Southern California was organized and commenced to function. Southern California agencies had committed themselves to the building of great works and the expenditure of many millions of dollars. But the Colorado River remained a political football in Arizona, and governors and other state officials were being elected or defeated on the issues of the river, but still there was no ratification of the compact by Arizona.

Arizona, in furtherance of its contention that the waters of the Gila River were exclusively used by it, sought by its second action filed in the Supreme Court, in 1934 (*Arizona* v. *California,* 292 U.S. 341), to perpetuate testimony to the effect that the compact commissioners intended that the million acre-feet of water referred to in Article III(b) was intended for Arizona in compensation for the Gila River waters then being used by Arizona, and that a supplemental compact between Arizona, California and Nevada, so providing, had been agreed to. Arizona contended that the million acre-feet of III(b) water was hers, but that California claimed the right to draw upon such water; and that the Secretary of the Interior had made his contract with California for 5,362,000 acre-ft., which included III(b) water. The Supreme Court held that Arizona could not be bound by any contractual provisions of the compact since she had not ratified it, and that, as far as the compact went, the III(b) waters were not for Arizona alone but for the whole lower basin.

Constructions of Hoover Dam, of Imperial Dam, of the All-American Canal, of the Metropolitan Aqueduct were all going forward—and Arizona still refused to ratify the compact. But she feared what California was doing about using the Colorado River waters. So, in 1935, she filed her third case in the Supreme Court (*Arizona* v. *California,* 298 U.S. 558), seeking a partition—an equitable apportionment of the waters of the stream. California and the other five basin states were the defendants, but the United States was not so named. In this case, Arizona sought to bar California from any right to divert more water than as limited in the project act and limitation act, to require that any rights of Mexico should be supplied from California's share, and prayed that Arizona's share of the water be determined. The Supreme Court reviewed the situation on the river and dismissed the case, holding that the government's interest in the river was such—because of the dam, because of the project act authorization for the storage of the water and its delivery by government contracts—as to preclude a determination of the case without including the government as a defendant.

The dam was finished in 1936; the Metropolitan Aqueduct in 1941; Imperial Dam and the All-American Canal were constructed (Fig. 3); and Colorado River water flowed into southern California, to quench the thirst of its people and of its lands. Arizona had not yet ratified the compact, and it had no contract from the government for the delivery of any water to it. Then it was that Arizona, in 1944, ratified the compact and se-

cured its own water contract from the government. California has relied—and now relies—upon its basic rights and upon its contracts from the government, because of which so great an amount of money has been expended; and California contends that Arizona's contract is, and in the nature of things must be, subordinate in many particulars.

Then came the Mexican Treaty, ratified by the United States Senate in 1945. Arizona supported that treaty; California opposed it. Where does the Mexican water come from—who furnishes it?

The great trouble is with the amount of water that is available. There just is not enough for all claimants to be satisfied. The compact has never been judicially construed, and the basin states are in conflict over its provisions. Arizona contends that the III(b) water is "apportioned" by the compact, and that California, by its limitation act, has excluded itself from any part of those waters; California denies this. California contends that Arizona, in its consumptive use of the Gila waters, must be charged against its basin allotment, and hence reduced in its take from the main stream; Arizona opposes this.

Officially, Arizona has refused to enter into negotiations seeking a subcompact or the arbitration of the disputes, and it opposes California's efforts to get the controversies settled. Arizona has contented itself with claiming that all disputes have been settled and its rights have been determined, and on this predicate it has sought—and still seeks—Congressional authority for the building of projects for the purpose of diverting water into Arizona. California opposes those projects before the Congress and insists that no new projects be built for the consumptive use of water within the lower basin until the rights of each state have been settled.

As this paper is being written, Arizona is seeking authorization of its "Central Arizona" project to divert 1,200,000 acre-ft. annually into the state, with a lift of 1,000 ft., at a preliminary cost of $600,000,000 and an ultimate cost of over a billion dollars (9). California claims this water and opposes the project. California seeks a final determination of all of the issues by decree of the United States Supreme Court, and to this end there has been offered in Congress a joint resolution which contemplates the filing by the government of an action in the Supreme Court of the United States against the lower basin states for the purpose of determining all claims against and rights to the use of the waters of the Colorado River System available for use in the lower basin. Arizona opposes this, and contends that all issues are settled and court decision is unnecessary.

What is the law? Where are the equities? A billion dollars is a lot of money to spend in a state where the whole assessed valuation of all taxable property is probably one-half of that amount.* Arizona has a population (estimated) of about 600,000 people, whereas the assessed valuation of the Metropolitan Water District area is over 2.5 billion dollars, and its population is about 3.5 million people.† No invidious comparison is meant by

* The 1940 *Economic Almanac* gives Arizona's assessed valuation for that year at less than $390,000,000.

† On authority of Julian Hinds, Chief Engr. and Gen. Mgr., Metropolitan Water District of Southern California, Los Angeles.

these figures. It is more important that it be finally determined just what amount of water may be legally used in Arizona and California, respectively, and that the enormous amounts of requested government-project money be spent only upon the definite assurance that water is legally available for allocation to that project.

California has shown vision, courage, and adventure in the spending of over a half billion dollars of its money, without governmental or other subsidy, in the development of its works to use the water and power from the river, whereas Arizona and other states have depended—and still depend—on heavy governmental subsidies for the support of their constructed and potential projects.

Where stands the law and equity? What are the economic implications of the figures that have been given? There is no intention to intimate that Arizona, because it is small, should be unfairly dealt with, or that California, because it is large, should have more than it deserves.

The Arizona-California controversy is real; it is acute. The river is not big enough to satisfy the demands of both states, and something must give. No alternative to a decision by the nation's highest court is seen. To that court California stands ready to present its case; upon its decision California confidently rests.

California's Stake

The Boulder Canyon Project Act required that power and domestic water contracts be obtained by the government, sufficient to pay the full cost of Hoover Dam, before any construction work was started. Southern California agencies, including the Dept. of Water and Power of the city of Los Angeles, did make those contracts, and guaranteed that every dollar spent by the government in the building of Hoover Dam, in its operation and maintenance, in the renewal and replacement of its equipment, together with interest, would be paid. The government's expenditures in the construction of and equipment in the dam is \$125,000,000. The cost of the building of Parker Dam and the Metropolitan Aqueduct, to be paid for by southern California water users, is \$274,000,000. The cost of the building of Imperial Dam and the All-American Canal, in the Imperial Valley, is \$78,000,000; that of extending the Metropolitan Aqueduct to the city of San Diego is \$16,000,000; and that of the transmission lines carrying the power from Hoover Dam and Parker Dam is \$56,000,000. These items total \$549,000,000—certainly important money in any language. Users of electrical energy generated at Hoover Dam also pay nearly \$7,000,000 of annual operating and maintenance; amortization and other expenses, including payments of \$300,000 in lieu of taxes to each of the states of Arizona and Nevada, and including also the sum of \$500,000 to continue studies and investigations of the whole river system by the Bureau of Reclamation.

It has been said that, within the foreseeable future, the population of southern California will comprise 10 million people. The lazy, pastoral life of the California *hacendados* has gone forever, and the giant of Industry and Agriculture must turn the wheels and till the fertile lands of southern California that its people may live in comfort, in prosperity, and in peace. To this destiny, our forefathers dedicated themselves; to this destiny, our people have mortgaged their homes and their lands; for what is the past is but the

prologue of the great civilization that can yet be. The vision, the adventure, and courage of our people, tied to the great resource that is the Colorado River, has pointed the way.

Conclusion

California considers itself in partnership with its sister states of the lower basin. It furnished some money, and a great dam was built, conserving some millions of acre-feet of water that had been wasted to the Gulf of California. Other states have furnished water and the land on which the dam was built. Interstate trade, to an extent not believed possible, has grown; the states have flourished; the government has benefited—and all from a river, the resources of which have been barely tapped.

Eventually the legal difficulties incidental to an interstate division of the water of the Colorado River, with due regard to its dependable flow, will be settled, and its water will be utilized to the last drop; its power to the last kilowatt. This is a job so great in its possibilities that only a nation of free people can have the vision to know what can be done, and the courage to do it. The Colorado River is the heritage of the great Southwest, and remains its greatest natural resource. It will preserve to our peoples and our lands the blessings of comfort and prosperity. The development of the river is not yet complete. Many large dams for the impounding of water, to further control floods and the deposit of silt, to water additional lands, and to expand the great hydroelectric production from its falling waters, are yet to be built. The treasure of the water of the Colorado River, the bounty of its power, controlled and developed and put to use, in their implications and potentials, will furnish the economic backbone of tens of millions of people. The Colorado River is today, and will be tomorrow, the greatest resource of the Southwest, and the destiny of the Southwest will not be denied.

Acknowledgment

Material has been gathered from many sources, and acknowledgment is due to a number of publications (12–16) not specifically referred to in the text.

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Ground Water—A Neglected Natural Resource

By Malcolm Pirnie and Robert W. Sawyer

A paper presented on July 22, 1947, at the Annual Conference, San Francisco, by Malcolm Pirnie and Robert W. Sawyer of Malcolm Pirnie Engrs., New York.

ACCELERATED studies of the ground water systems of our country are required in order that their safe yields may be intelligently developed and conserved by proper use and protection. Otherwise, natural ground water assets of great value will be added in increasing numbers to those systems which have been destroyed.

People deal practically with the seen and embark upon wild flights of imagination about the unseen. Typical of imaginative beliefs are: that the bubbling spring has its source in Shangri-La; that near Schenectady, N.Y., an underground river from the Adirondacks flows in a mythical pre-glacial channel; and that the ground waters of south Florida are supplied by a subterranean river from the hills of Georgia. For such pleasing mysteries about the source of ground water must be substituted the prosaic fact that it comes from the rain falling upon the good earth, which varies in its capacity to receive and store part of the rainfall and permit it to flow laterally to discharge at a lower elevation in a spring, lake, river and finally into the oceans.

Congressional Appropriations

The degree to which appreciation of value of the seen exceeds appreciation of value of the unseen is clearly demonstrated in the 1948 Interior Dept. Appropriation Bill, Calendar No. 282 in the Senate. The Bureau of Reclamation, engaged principally in the regulation and use of surface waters in the seventeen arid states, has a total appropriation of $37,012,932. Under the item entitled "Gaging Streams" in the Geological Survey there is a total appropriation for activities throughout the entire country of only $2,625,000, yet this amount includes the funds for ground water studies. The Senate Committee on Appropriations recommended that the House prohibition against use of funds for co-operative or nonco-operative ground water activities contained in H.R. 3123 be stricken from the bill and that not less than $740,000 be used for co-operative or nonco-operative ground water activities.

What a pitifully inadequate sum! It is clearly insufficient to continue the co-operative ground water studies already initiated and will discourage expansion of studies essential to conservation and intelligent development of one of our most valuable natural resources. If properly developed and used, such resources will produce indefinitely an annual crop of fresh water to sustain agriculture and commu-

nity life over extensive areas of our lands. Can it be that some group of citizens, desirous of sustaining the mystery of ground water, urged the House Committee on Appropriations to prohibit use of any federal funds to record the facts needed to determine the source and safe yields of our ground water systems?

Value to National Defense

All the money which had previously been appropriated by Congress for the ground water activities of the Geological Survey was returned, many times over, by the use of the limited knowledge it had made available for economical development of water supplies and conservation of strategic materials in recent war installations and activities. Adequate appropriations for continuance and expansion of these fact-recording activities of the Geological Survey can therefore be justified upon the grounds of national defense alone. Encouragement of co-operative procedures with political subdivisions will pay cumulative dividends to advance the standard of living in the peace economy.

A brief listing of several experiences with ground water production works in recent years will serve to emphasize the value of records resulting from activities of the Geological Survey and other similar investigations.

California, conscious of the value of water wherever it may be found, has established essential facts and kept records of operation of many ground water systems. Within a few days, Arthur M. Piper, Senior Geologist, U.S. Geological Survey, made available existing knowledge applicable to the selection of water supply sources for several Army installations on the West Coast which would have taken many months or even years to obtain at first hand.

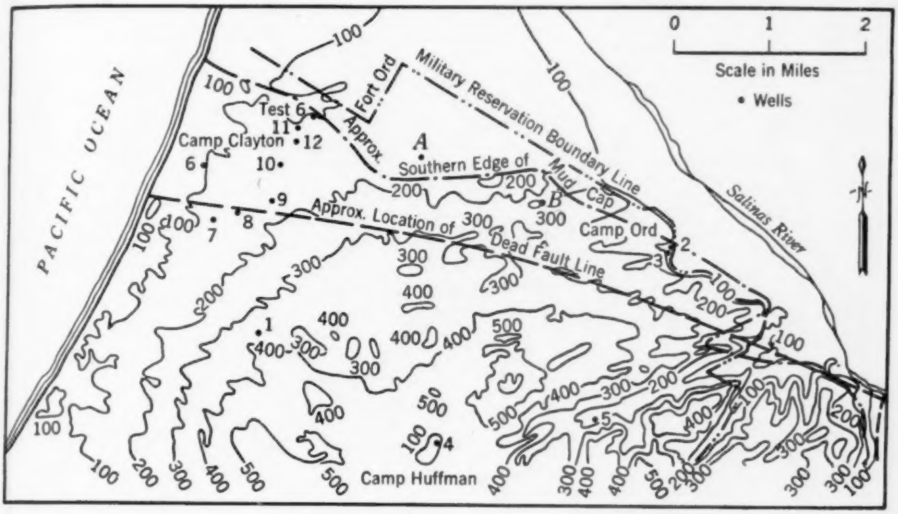

Fig. 1. Northern Part of Fort Ord Reservation

Wartime decisions cannot wait for time-consuming investigations; they must be made immediately. Without the important facts developed during past years, large sums of money could

have been wasted in attempted development of inadequate ground water sources or extensive surface water supply works, and large construction projects simultaneously rushed to completion for rapid mobilization of the full tion of these four water supply works had been delayed by criticism of plans submitted to the Quartermaster General, and a review of water supply sources for these installations was ordered.

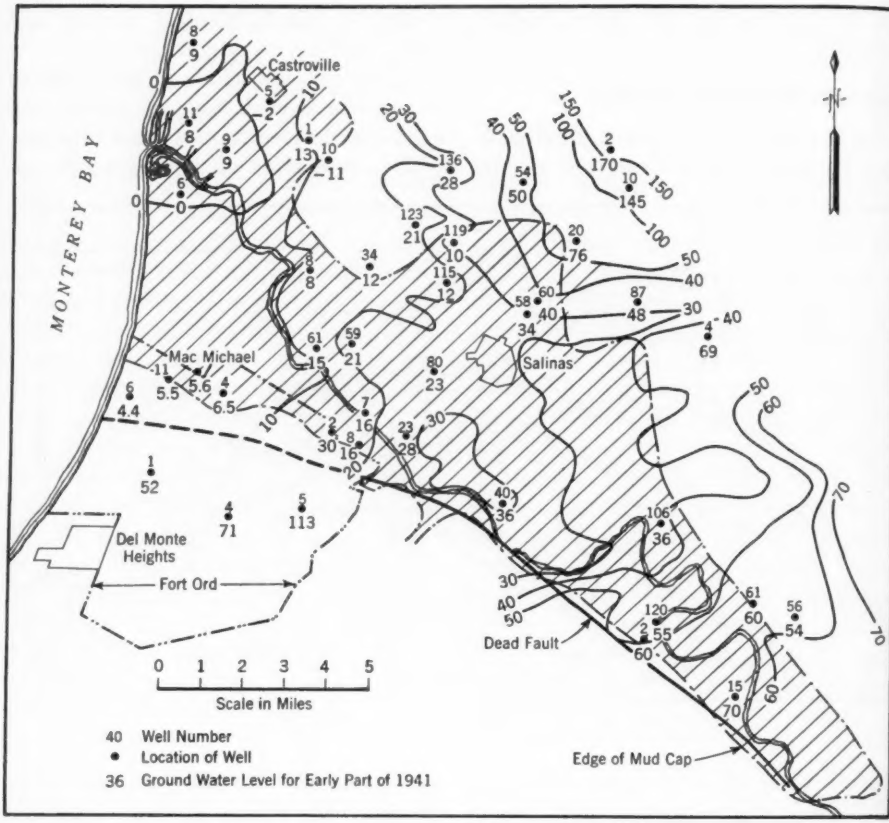

FIG. 2. Piezometric Contours of Lower Salinas Ground Water Basin

strength of the nation could have failed to serve their purpose. Available data supplemented by field studies and minor explorations established beyond doubt correct selections of sources of water supply during the summer of 1941 for the important Army installations at San Luis Obispo, Santa Maria-Lompoc, Camp Roberts and Fort Ord, Calif. The authorization for construc-

San Luis Obispo

No adequate ground water systems were found within economic reach of San Luis Obispo. Accordingly, the construction of a dam creating an impounding reservoir in the Salinas River Valley was built, as originally recommended by the Architect-Engineer, to provide a surface water supply.

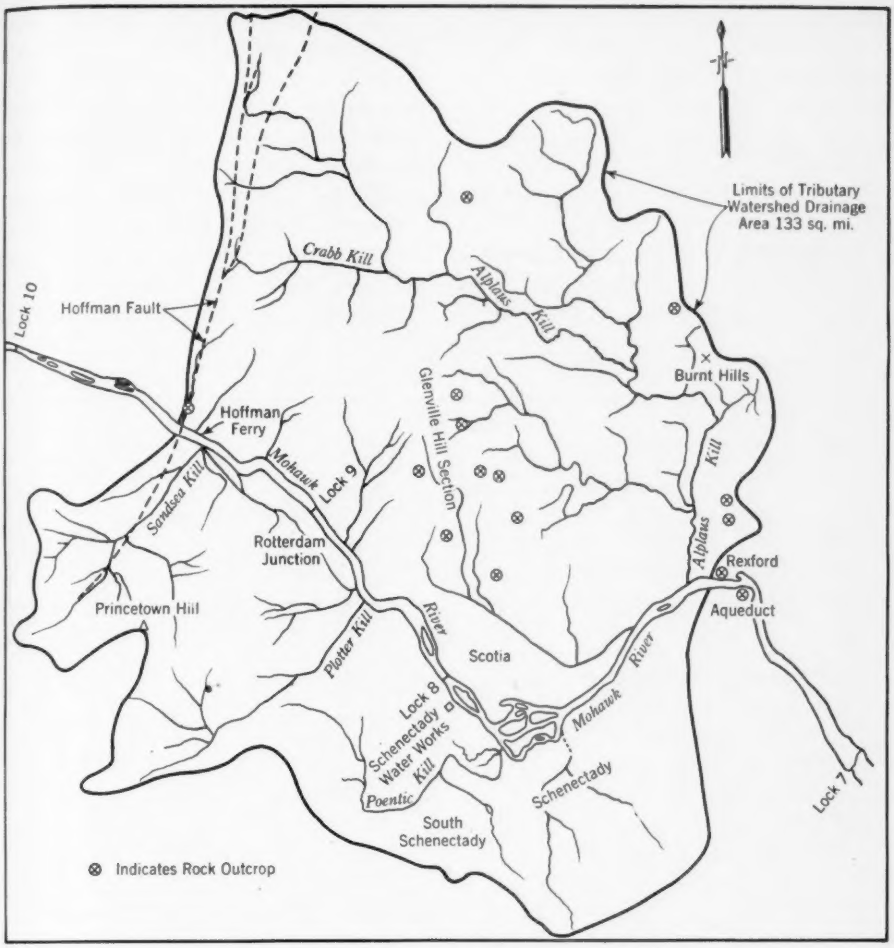

FIG. 3. Watershed Area of Schenectady, N.Y.

NOTE: For the most part the area is underlain with glacial till and flood deposits consisting of boulders, gravels, sands and clays. The southern portions of the watershed are principally underlain with wind-blown sands and stratified sands grading into underlying sandy clays. There are also evidences of rock outcrops as shown, principally in the Glenville Hill section.

Santa Maria-Lompoc

The alluvial plain ground water system of the Santa Ynez Valley at Lompoc was already developed close to its safe yield limit for irrigation and domestic uses. Conservation of runoff annually lost to the sea was required to raise the safe yield of the system to provide ground water needed to supply the Army installation on Burton Mesa. To increase the system's storage capacity and retard sea water intrusion, a sheet pile cut-off dam was constructed across the narrow part of the river valley near its mouth. The ground water spillway elevation was thereby raised above the highest of the fluctuating tide levels. Treated sewage and other waste waters from Army operations were discharged above the

dam, and water supply was obtained from wells at some distance up the river near the north edge of the alluvial plain.

Camp Roberts

At Camp Roberts, straddling the Salinas River, nine existing wells averaging 700 ft. in depth passed through alluvial terrace gravel to obtain a total supply of about 5 mgd. from the underlying Paso Robles formation. This formation consists of slightly consolidated gravel interbedded in sandy and marly clay. The static level of this artesian supply was about 20 ft. above the river level. After about 30 hours of operation, four typical wells yielded water of chemical character varying as follows: alkalinity, 309–409 ppm.; sulfate, 105–346 ppm.; chloride, 56–472 ppm.; hardness, 95–255 ppm.; iron, 0.02–0.1 ppm.; calcium, 16–48 ppm.; and magnesium, 13–33 ppm. The outcrop belt of the Paso Robles formation in the vicinity of Camp Roberts, some ten to fifteen miles wide on the east bank of the alluvial plain, was undoubtedly extensive enough to capture sufficient ground water from rainfall to compensate for the developed draft from wells. It was recommended that development of better quality water be attempted, however, by means of gravel-packed wells of much less depth in the upper alluvial gravels.

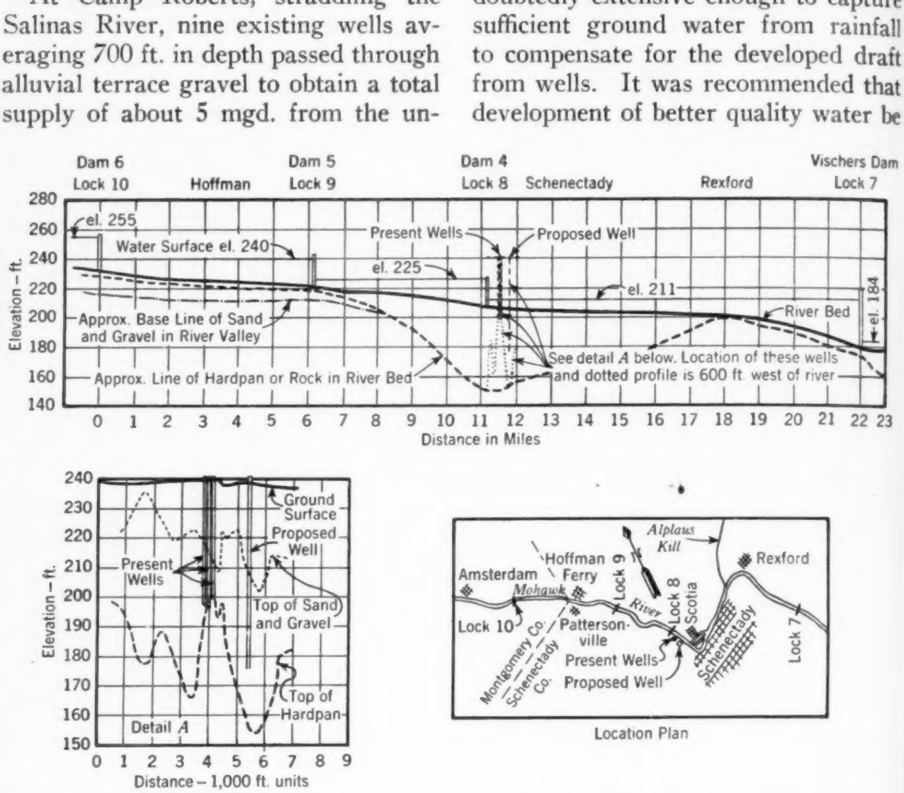

FIG. 4. Diagrammatic Profile of Schenectady Ground Water Reservoir

Fort Ord

The drilling of wells much deeper than were needed to obtain equal quantities of better quality water had been completed at Fort Ord as at Camp Roberts. Although the principal water-bearing zone was found less than

100 ft. below sea level, the five gravel-envelope wells in use had been drilled to between 600 and 700 ft. below sea level. All were near the northwest corner of the reservation within 1½ miles of the coast (Fig. 1). The static water level was only 6 ft. above mean sea level, an amount which was sufficient to balance sea water pressures to the relatively shallow depth of no more than 250 ft. below sea level. Logs of a similar well located ½ mile from the coast.

Although wind-worked sands continue northward past the reservation's north boundary, at elevations between 100 and 200 ft. above sea level, in a narrowing and declining ridge to the present mouth of the Salinas River, it was apparent that the Marina terrace of the "Salad Bowl of America" was laid down beneath this much younger

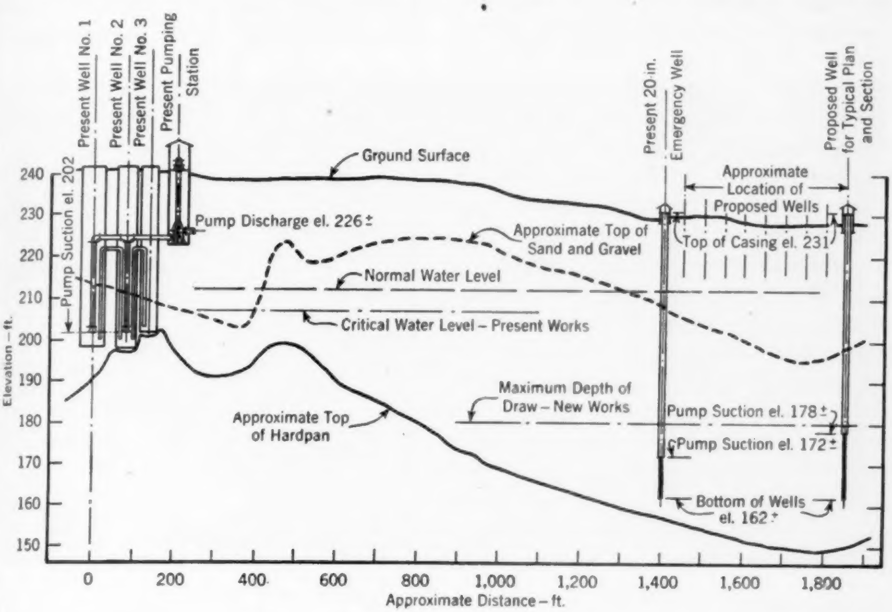

FIG. 5. Surface and Underground Conditions at Schenectady Wells

the two wells nearest the north boundary of the reservations recorded a horizontal bed of coarse sand and gravel 31 to 55 ft. thick and with a maximum elevation of − 32 ft. This is an ideal aquifer in which to develop gravel-packed wells and probably furnished the major part of the ground water feeding the gravel-envelopes of the existing deep wells. Otherwise, these wells would have salted, as happened after 70 hours of pumping with terrain. This conjecture was substantiated by test well *A*, surface el. 161 ft., which recorded the typical Marina formation mud cap close to sea level and a 40-ft. bed of coarse sand and gravel underlying it. The 160 ft. of mud column in the rotary-rig-drilled hole had effectively sealed this aquifer so that it was reported to contain no water, and drilling was continued to 800 ft. below sea level in the Paso Robles formation. It was established.

however, that properly constructed gravel-packed wells developed in the Marina coarse sands and gravels could be located at a safe distance from the coast near the north boundary of the reservation.

Long-term records established by the ground water investigations of two California agencies described formations penetrated by existing wells and also the water levels during wet and dry weather cycles in both the Salinas and Santa Ynez alluvial plains. Water levels were available for the spring of 1941 compared with the levels in 1932, which were, in general, from 5 to 10 ft. lower. If such essential records (Fig. 2) had not been available, plans could not have been adopted to use waters otherwise flowing to waste from these fully developed agricultural plains. In these circumstances, government emergency requirements could have resulted in serious depletion in agricultural production and substantial damage payments. Existence of the records made possible the permanent increase in dependable yield of the Santa Ynez ground water system and the use of wasted waters from the Salinas system.

Schenectady

Fifty-three years ago the city of Schenectady, N.Y., dug a well 43 ft. deep, 8 ft. wide and 60 ft. long to tap the mythical "subterranean river from the Adirondacks." It was located close to the west bank of the Mohawk River three miles northwest of the center of the city (Fig. 3). The capacity of the first well was reached at the turn of the century, and, in order to continue to supply the water requirements of the city, two new wells located successively southeast of the first well were constructed in 1903–04. In digging these wells, impervious hardpan was encountered on a rising pinnacle at the bottom of the ground water basin. The normal capacity of the three dug wells was exceeded in the late winter of 1940. The demand for water was barely met by raising the ground water escape level into the river

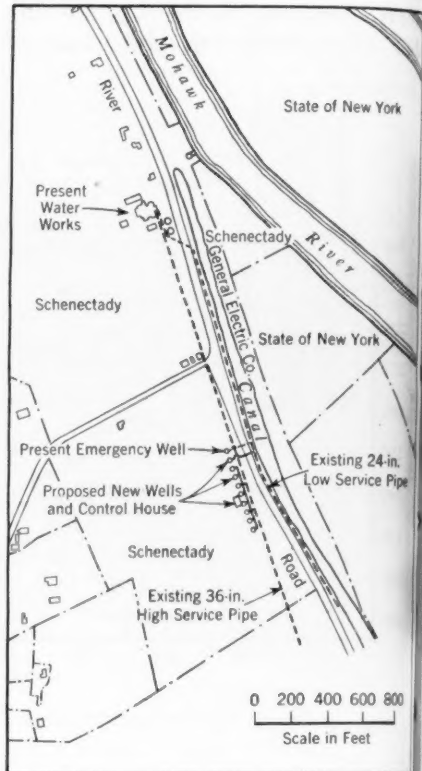

Fig. 6. Location of New and Old Schenectady Water Works

behind flashboards maintained on Vischer's Dam below Schenectady, until spring floods carried them away. This raised the depth for lateral flow of ground water above the hardpan into the wells.

Fortunately, geologic studies and recent ground water investigations had

established the general limits and nature of the ground water system at Schenectady (Fig. 4, 5). Hurried supplemental investigations located an arm of the ground water basin 45 ft. deeper than at the existing wells. This arm was filled with clean coarse gravel ranging up to cobble stones in size. It was ⅓ mile southeast of the original well. Existing 36-in. loop and 24-in. supply mains crossed the site. In February 1940 the first well was drilled at this site. A 20-in. casing was sunk to a depth of 50 ft. below the ground water surface, and a 12-in. inner casing and 30 ft. of No. 45 slot copper-silicon alloy * screen were inserted. The development with gravel packing was accomplished at rates of pumpage up to 5 mgd. as the outer casing was gradually withdrawn to expose the screen; and the completed well was tested, equipped and placed in regular operation to deliver 3.5 mgd. to the 24-in. supply main serving the low-pressure zone in the city. All of these operations were accomplished by day and night work in 14 days.

Work on nine similar wells with 24-in. outer and 18-in. inner casings, the bottom 20 ft. of which contained a total area of 5.2 sq.ft. of slotted openings, was started early in October 1942 and completed in less than five months. They are located in a straight line 50 ft. apart (Fig. 6). Two groups of four wells were test pumped, each at the rate of 20 mgd. Drawdowns inside the screens ranged from 4 to 5 ft. Drawdown in an idle well 50 ft. from the four under test was only 1.3 ft.

FIG. 7. Air View of Schenectady Water Works

The total cost of these thoroughly equipped new ground water production works, which are rated at 30 mgd., with ample stand-by equipment, and including the buildings (Fig. 7) was $480,000. Knowledge of the unseen, which was not available in 1894 nor in 1903, made this economical development possible with a substantial saving of strategic materials at a time

* The copper-silicon alloy referred to is "Everdur," a product of the American Brass Co., Waterbury, Conn.

when they were sorely needed for wartime industrial expansion.

Fort Dix

By December 1940 the water supply and distribution system built in 1917 for Fort Dix, N.J., was failing to deliver the needed supply. A new filter plant had been constructed at one corner of the distribution system to treat the highly colored water pumped from Rancocoas Creek through a long supply main. To continue Rancocoas Creek as the source of supply, a new supply main, additional filter plant capacity and substantial reinforcement of the distribution system were required. To build these would consume substantial amounts of critical materials and greatly delay planned functioning of this expanding Army receiving center. Between Christmas and the last day of 1940, the clear well of the new filter plant was converted into a ground-level receiving reservoir to increase the discharge of the supply main, and a booster pump trucked from the New York World's Fair fountain was installed to boost the water to distribution pressure.

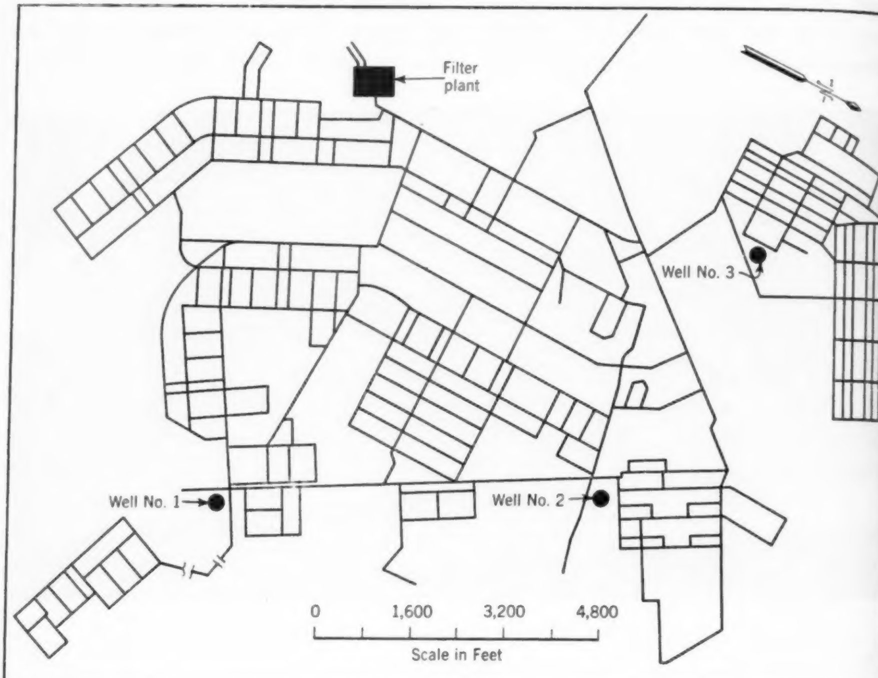

FIG. 8. Placement of Wells to Increase Capacity of Fort Dix Distribution System

Unfortunately, there had been no ground water activities of the Geological Survey in this area, and one attempt to drill a well in 1917 had failed. Nevertheless it was reasonable to believe that aquifers in the Raritan-Magothy formations would be found below some 800 ft. or more of overlying clays under Fort Dix. A 20-in. well was started immediately near one of the three corners of the old distri-

bution system grid distant from the filter plant. Work was continuous day and night. A sand lens of the Magothy formation was ultimately reached under nearly 1,000 ft. of clay. After exploration a 10-in. inner casing was inserted and driven through the sand; copper-silicon alloy screen was inserted, gravel was fed between the casings as the inner one was withdrawn; and water was pumped to remove the fine sand and allow its replacement with gravel. This well was gravel-packed until it yielded clear water at pumping rates of 1.25 mgd. It was then equipped with a 1-mgd. deep well pump discharging through a connection to the distribution main. The additional supply was available May 22, 1941—108 days after starting the well.

Similar wells were installed less hurriedly near each of the remaining two corners of the distribution grid. Thus with water introduced near each of the four corners of the old distribution grid (Fig. 8), its capacity to supply peak demands was made adequate without the installation of several miles of reinforcing mains.

Conclusion

These brief recitals of the development of a half-dozen critical water supplies needed for the war program should be sufficient to emphasize the importance and inestimable value of recorded facts about ground water systems. No more necessary and useful expenditure of federal funds can be made than that needed by the U.S. Geological Survey to carry out and expand its program of ground water investigations in co-operation with the various political subdivisions of this country.

Acknowledgment

Information presented in this paper about California and New Jersey water supply projects was obtained from services rendered by the authors as consultants to General Brehon B. Somervell and information about Schenectady from services rendered to that city under the resident direction of Robert W. Sawyer.

Discussion

Arthur M. Piper

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This stimulating paper suggests the kind of critical water supply problems which faced the nation early in World War II. Under an urgency that afforded the barest minimum of time for investigation and none for correcting serious errors, it was necessary to estimate the adequacy of undeveloped water sources available to serve numerous military or industrial installations, of which many would create an immediate water requirement equal to that of a fairly large city. Commonly the requirement was many times greater than the capacity of any water development works previously undertaken in the vicinity, so that local experience afforded no dependable "yardstick."

Because ordinarily they could be brought into production more quickly, or because no others were available, ground water sources generally were given first consideration. For these, it was necessary to estimate behavior under heavy drafts projected several

years into the future and to plan their development to minimize any permanent depletion, to avoid drawing in salt water at installations near the coasts, and otherwise not to destroy water sources which constituted the reserve for peacetime developments.

For this task the U.S. Geological Survey undertook to assemble and digest pertinent information from all available sources—as well from the work of numerous state and local agencies as from its own effort over the preceding half-century. In the attack on the problems in California, in which the writer was briefly associated with coauthor Malcolm Pirnie, a large part of the pertinent data was drawn from the findings of investigations which had been carried on by the state and other non-federal agencies over many years. For problem areas in California, reasonably adequate background information generally was available; elsewhere, such information was fragmentary indeed. Both good judgment and good fortune contributed to a successful effort.

In the event of another global war, the United States well might be faced inescapably with very wide dispersal of its military and industrial installations. To provide adequate and dependable water supplies under such a contingency would indeed be a task of first magnitude. Should the contingency arise, and should our investigations of water resources have continued only in the scope and on the schedule which have been conventional in the past, the nation then would face its water supply problems with a store of knowledge pitifully small indeed. It is sincerely to be hoped that this contingency will not arise, in either the early or the remote future. None the less, prudence suggests that the nation diligently arm itself with intimate knowledge of its potential water resources, both for the expanding demands of its peacetime economy and for emergencies of the future.

Water Development and Salt Water Intrusion on Pacific Islands

By Frederick Ohrt

A paper presented on July 21, 1947, at the Annual Conference, San Francisco, by Frederick Ohrt, Gen. Mgr. and Chief Engr., Board of Water Supply, Honolulu, T.H.

CONDUCT of the Pacific war, especially in the southwestern and western Pacific, with lengthening supply lines for every sort of war material, brought the development of island water supplies into great prominence. Water supplies on oceanic islands (Fig. 1), especially small ones, face a constant threat from salt intrusion. Because of extensive water development in Hawaii, especially in the Honolulu and Pearl Harbor area, water engineers in Hawaii have probably acquired as intimate knowledge of the fresh water-salt water balance as people have anywhere. Hence in discussing the problem and the general principles involved, the references will be largely to conditions in Hawaii, at Honolulu on Oahu (Fig. 2).

Most of the islands of the central Pacific either have been built up of successive lava flows from the ocean bottom or have the form of low coral caps on the tops of earlier volcanic islands. Oahu will serve as a type of such an island. The beginnings of Oahu came perhaps 5 million years ago, when two adjacent islands began forming and rising from the ocean floor (Fig. 3). After the westernmost cone was built above sea level, the eastern cone started, and the outpouring lava flows built it above sea level and against the western cone, which by that time had already been somewhat eroded. Practically all the saddle area, on which Schofield Barracks stands between the cones, consists of lava flows from the eastern or later volcano. All this may have taken 2 or 3 million years. Important later stages were the deep erosion of the lava masses, the erupting of secondary volcanoes like Diamond Head or Punchbowl, the growth of fringing coral reefs and the formation of a wide coastal plain or caprock that extends from Diamond Head to Barbers Point along the Honolulu and Pearl Harbor shore. This may have been completed a quarter or half million years ago.

Rainfall

All these islands are dependent upon rainfall for water supply, whether it is developed from streams or from the ground. Only the larger islands have perennial surface streams. Most of the smaller islands and many sections of the larger islands must turn to ground water for useful water supplies. The development of water from ground water sources will be better understood if a preliminary discussion is offered of the process of absorption of the rainfall by some of the Pacific islands.

The water from rainfall, absorbed into the ground of a permeable island, passes downward to become part of a

permanent body of ground water. If such an island is permeable both above and below sea level, the part below sea level would at first be saturated with sea water, either by entry from the sides or by incorporation when the island was built (Fig. 4a). The simplest condition is that of an island in the ocean without rainfall. If there is rainfall, the water passes downward into this permeable island until it reaches sea level, where it accumulates water equal to its own weight, and therefore the fresh water presses downward to form a deep bulge of fresh water extending below sea level. Both theory and actual measurements in deep artesian wells indicate that, when the floating balance is reached, the fresh water extends about 40 times as far below sea level as it does above sea level. This ratio exists because the salt water is about 41/40 as heavy as fresh water.

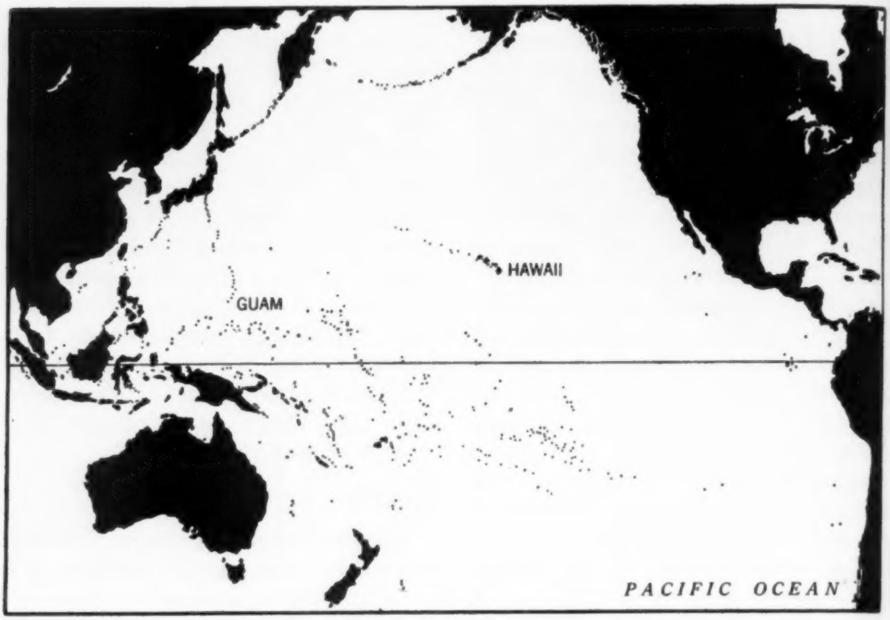

FIG. 1. Islands in the Pacific Ocean

and spreads on top of the salt water. At the shores of the island it tends to escape as seepage and springs, and the interior part builds up a mound of such height and slope that the rate of escape equals the rate of addition from rain.

The fresh water standing above sea level is really floating on the heavier sea water. Like other floating objects it must displace a weight of the salt

Ghyben-Herzberg Lens

In a circular island, with uniformly permeable rock structure, the fresh water forms a double convex lens, with the larger part below sea level and with the circular, sharp edge of the lens at the coast (Fig. 4b). This lens is known as the Ghyben-Herzberg lens, from the two investigators who recognized this condition along the North

Sea coast of Holland and Germany about 1890 (1–3).

Now, if erosion and formation of a coastal plain provides an impervious patch or caprock along a part of the coast of such an island this may retard the escape of the fresh water and cause the Ghyben-Herzberg lens to become greatly thickened, still keeping this remarkable ratio of about 40 to 1 between the bottom and top parts (Fig. 4c). This is the condition in the Honolulu area, where much of the coastal plain surface stands at a level less than the height inland of fresh water above sea level. Under such conditions, the water in the Ghyben-Herzberg lens, which is penetrated by numerous wells drilled through the caprock, is under artesian pressure sufficient to produce flowing wells over large parts of the lowland.

Because the principle of hydrostatic or U-tube balance is so important, it is set forth more formally in Fig. 5. Sea water, with specific gravity of about 1.025, is about 1/40 heavier than fresh water. The fresh water column, to balance, must be about 1/40 higher than the sea water column. Hence the fresh water lens, with a total thickness of 41 units, floats with 1 unit, or foot, above sea level for every 40 units, or feet, it extends below sea level. A brief explanation is that in the well there is a column 41 units high, of water of density 40, balanced against a column of sea water 40 units high, but of density 41. The more precise ratio at Honolulu, based on many

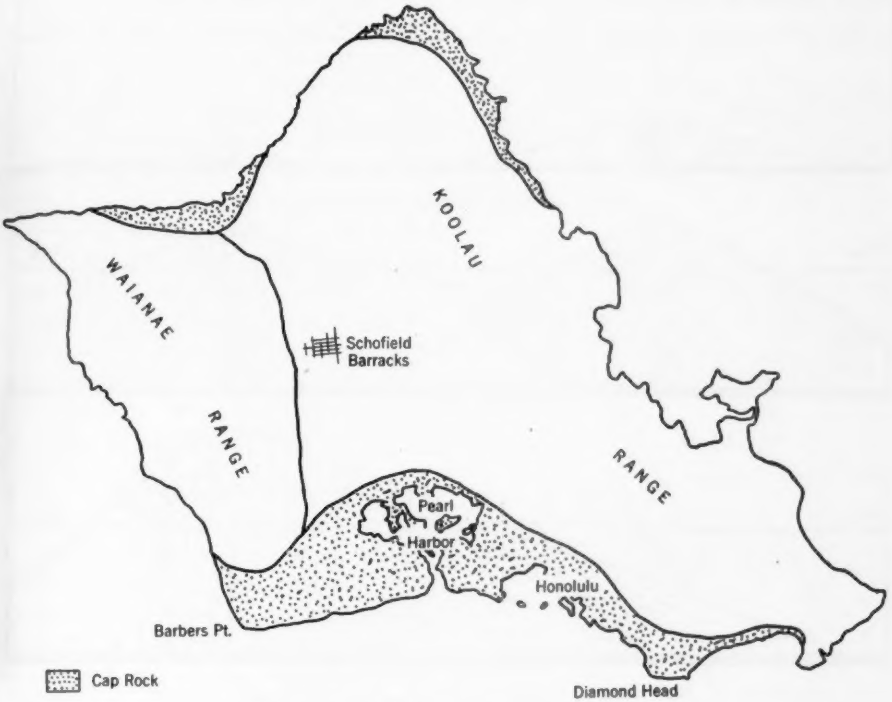

FIG. 2. Oahu in the Hawaiian Islands

analyses of sea water, is slightly over 38 (4), but for ordinary purposes the round number 40 is used.

In a great many places, because of irregularities of rock structure, differences in rainfall or other interference, only a part of the Ghyben-Herzberg lens is present, but this part may still be in functional balance with the salt water and follow the same principle. principle is taken into account, as far as its conditions seem to hold.

Honolulu Section

The south shore of Oahu, including the Honolulu and Pearl Harbor areas, because of the secondary craters, the growth of coral reef and the laying down of gravel and silt from the mountains, has a wide coastal plain on which the city and military installations are built. This coastal plain forms a remarkable caprock, back of which the fresh water is restrained and under which it develops artesian pressure (Fig. 6). Nearly 500 artesian wells have been drilled through it, and the behavior of these wells and the ground water during the past 70 years constitutes probably the largest body of data on the Ghyben-Herzberg principle

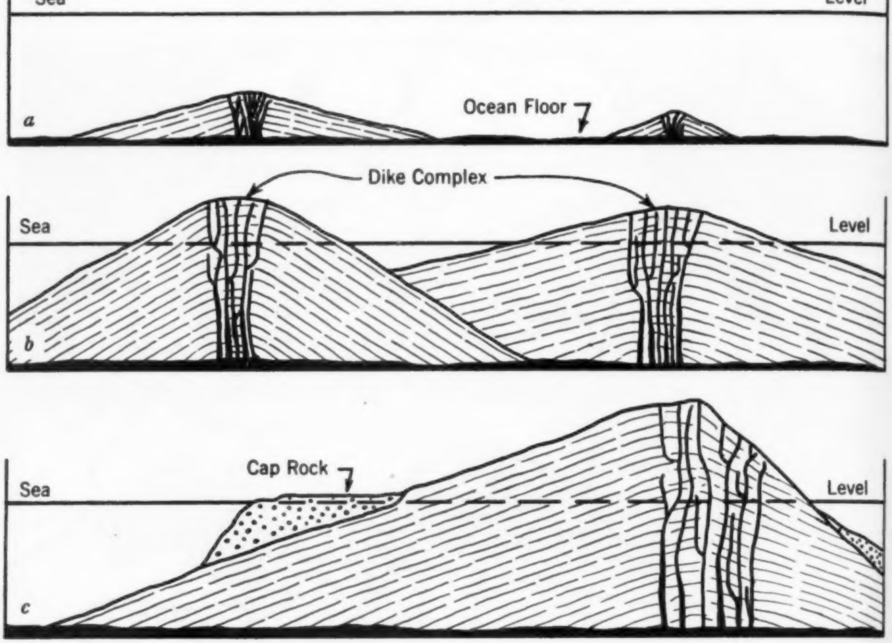

FIG. 3. Stages in the Growth of Oahu

This theory is emphasized here because on a great many islands in the Pacific area the fresh ground water most readily available anywhere on the island is found accumulated on the salt water and more or less in balance with that salt water. The amounts of water which may be obtained and the conditions under which successful development may take place are most readily understood if the Ghyben-Herzberg

that has been assembled anywhere in the world.

The original head of fresh water in the central part of the Honolulu area, in 1880, before depletion or salt intrusion started, was about 42 ft. According to the Ghyben-Herzberg principle, fresh water extended more than 1,600 ft. below sea level, and wells drilled to 1,200 ft. below sea level yielded fresh water, showing the substantial correctness of the theory of balance. In those days before the construction of any extensive system of water distribution, the presence of a flowing well of fine quality and freedom from contamination was a great boon, and many wells were drilled in the first two decades. As elsewhere, there was little control, and many of the wells flowed continuously with only partial use of the water. By 1910, there had been a material reduction of the head of artesian water and some wells no longer flowed freely. The chief distress felt at that time was shortage of water under the existing operating conditions.

Gradually a more serious consequence has become apparent. With lowering of head, according to the theory of balance, there should also be shrinkage or thinning of the bottom part of the lens to maintain the ratio of 40 to 1. It is apparent from Fig. 6 (even though a 10 to 1 ratio is used for convenience in drawing) that there is a much larger amount of water in the bottom of the lens than in the top. In theory, for every foot of lowering of the water table at the top, there will ultimately be a shrinkage of 40 ft. at the bottom, resulting in a rise of the salt water boundary, or transition zone, by 40 ft. It appears, both from theory and practical observation, that such shrinkage of the bottom portion cannot take place so rapidly as the loss of head at the top, because of the large quantities of water involved, but must lag behind by at least many months, possibly many years (5).

The sharp lowering of head in the Honolulu area, from 42 to somewhat under 25 ft., which took place by 1926, was somewhat reversed during the period 1926 to 1939, with help of favorable rainfall and a program of conservation. This was most fortunate because

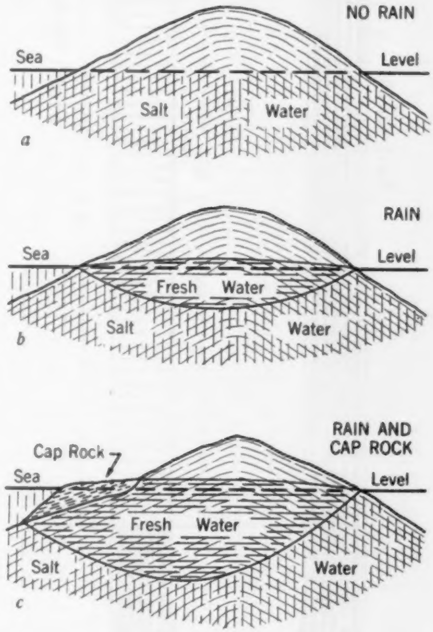

FIG. 4. Conditions of Rainfall Absorption in an Ideal Permeable Island

without it the war period, which brought greatly increased drafts, would probably have brought even more serious conditions. At any rate, heads were brought back down, during the three recent summers, to levels just under those of 1926.

Loss of Storage Reserve

Although, as has just been mentioned, concern was at first felt about

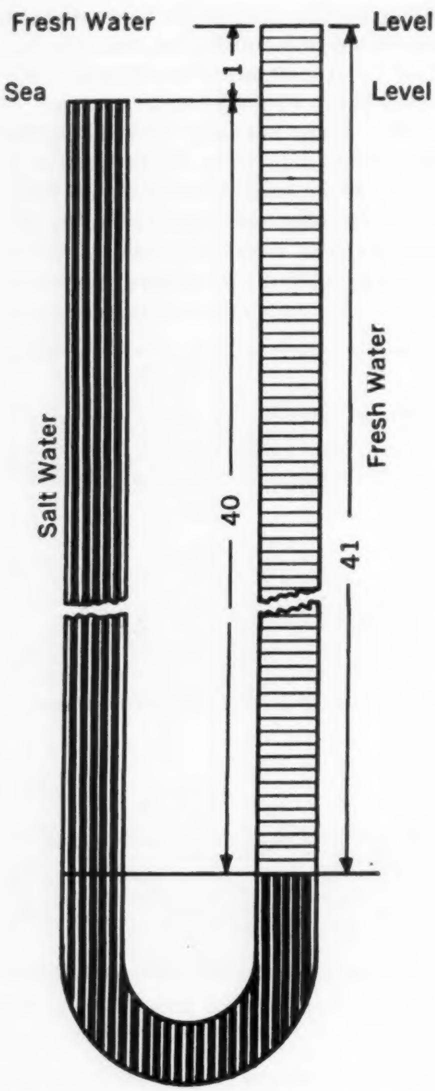

Fig. 5. The Ghyben-Herzberg Principle

the lowering heads, it is now known that the real loss in storage is taking place at the bottom. The steady increase in the salinity of many wells that earlier furnished fresh water is the result of this retarded, but sure, shrinkage of the lower part of the Ghyben-Herzberg lens, set in motion by the marked head lowering of earlier years and only now becoming evident.

The zone of transition between fresh water and salt is very irregular, and differs from well to well. Some wells show the effect soon and others of equal depth remain fresh longer, but the evidence is very clear that wells drilled below a certain depth, or in a position farther seaward, are now less likely to furnish fresh water than they would have been before the process of depletion and shrinkage set in.

There has been discussion in the past whether the process of salt intrusion is reversible and whether the salt water can be displaced if the water table rises sufficiently to cause the diffusion zone to move downward. The concept has recently been advanced that although the center of the diffusion zone may be moved back to its former position, successive alternating movements of the water in the rock will cause a thickening of the diffusion zone. If this is so, even if the center of the zone is restored, the water obtainable at a given level in the upper fringe of the zone near fresh water may remain much more saline than before any such intrusion and reversal took place (6). Practically, therefore, it appears that salt intrusion of potable waters is not a reversible process.

The shrinkage of fresh water below sea level must be regarded not only a destruction of conditions favorable to the draft of fresh water but also as a loss of an enormous storage reserve. The head loss, down to 25 ft., is about 40 per cent. Because of the lag in bottom shrinkage, a comparable loss at the bottom is apparently not complete, but is on the march; and there is probably nothing that can be done to reverse the process at this stage. This means that not only have we used

nearly half the reserves built up in this underground storage in geologic time (perhaps a half million years), but the rates of safe draft estimated in earlier years are too high, because part of the water used has come from this large, hidden reservoir. Accurate estimates are impossible, but the draft from storage for many years has possibly amounted to several million gallons daily, or 10 to 20 per cent of the daily total; and, once used, this is not available again.

of the earlier stages of water development were seen on Guam, Saipan and Tinian, and certain recommendations were made, designed to augment as well as to protect the water supplies. On the second visit to the same islands and to Iwo Jima, a few of the completed remedial installations were seen, but in general more advanced stages of the rather unfortunate, but perhaps necessary, assault on the natural ground water supplies were in evidence.

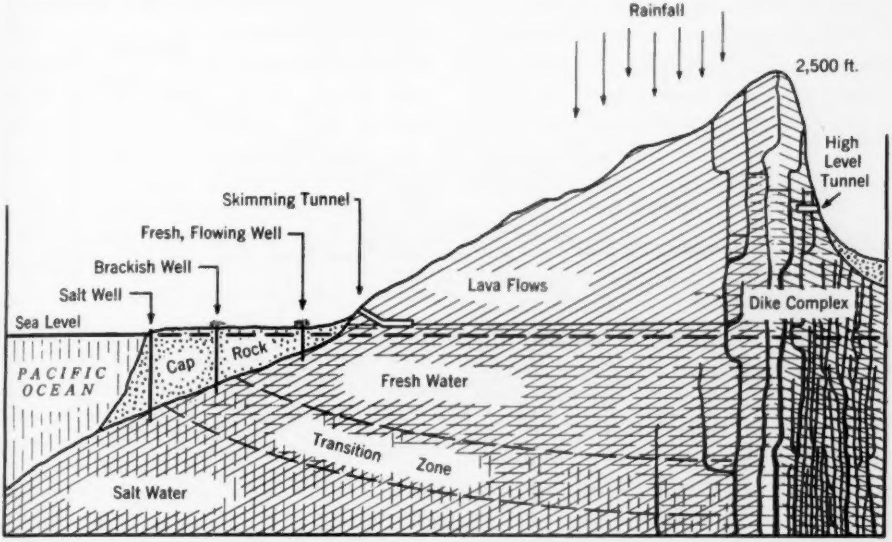

FIG. 6. Diagrammatic Section at Honolulu

Marianas Islands

Because of these experiences, and the development of certain practices designed to avoid further misuse of water resources, the author was very glad to have the opportunity, in company with Dr. Chester K. Wentworth, the geologist of the Honolulu Board of Water Supply, and Lt. Comdr. Paul H. Peterman, U.S.N., of making two visits of a month each to the Marianas, at the request of Admiral Nimitz. During the first visit many

On each of the islands visited, military invasion, followed by tremendous massing of men and equipment, created an immediate need for water supplies far beyond any developed natural resource. The first water available was supplied from ships as individual issues to landing personnel; next, distillation units for the production of drinking water from sea water were used. After making immediate use of known springs and local water supply installations, 6- and 8-in. wells were

drilled by various Sea Bee units at favorable points. There was a preliminary geologic report on Guam and some geologic information on Saipan and Tinian from captured documents. It was known that fresh water would be found in shallow ground water bodies floating on sea water in some places, but the first wells furnished more information of actual conditions.

In a large percentage of the wells, which were drilled to a few feet below sea level, fresh water was found and was put to immediate use. In many of the wells the water first obtained had a chloride content somewhat above that used in Honolulu, but still below the upper limit of 250 ppm. adopted by the U.S. Public Health Service. A few of the wells yielded water exceeding this limit which was nevertheless useful under these emergency conditions. The height of the water table, except in a very few places, was not over 2 or 3 ft. above sea level, and hence it was necessary to set the deep well pumps at or slightly below sea level. Because of these low settings and because of the critical demand for water, and more water, the continuous operation of these pumps nearly always caused a steady increase in salinity. The water in some wells became so saline that it could not be used, even under the extremely tolerant standards prevalent under urgent military conditions. A few of the wells were operated under schedules, or with limitations that kept the salinity low, but the unavoidable general conclusion was that most of the wells could not operate continuously nor approach their pumping capacity without forcing the salinity to intolerable levels and possibly doing permanent damage to the surrounding ground water (Fig. 7).

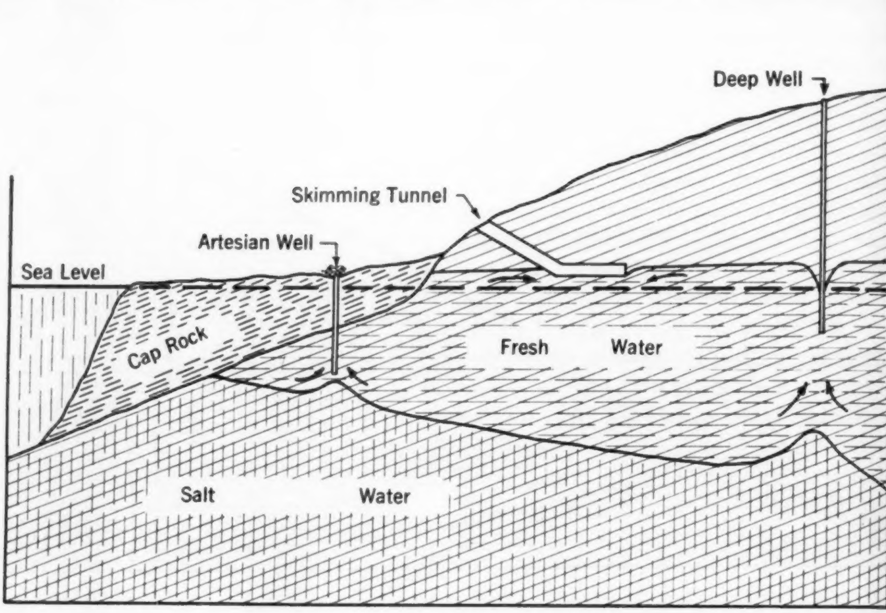

FIG. 7. Three Methods of Tapping a Ghyben-Herzberg Lens

This experience was a quick and convincing verification of the same process that goes on more slowly in Hawaii. A stage was reached in the Marianas in a few months that has taken more than 50 years at Honolulu. Experience in Hawaii has led to the increasing abandonment of deep wells and the substitution of skimming tunnels, and this change is well under way for many of the larger public and private water producers in Hawaii. A project of this sort consists of a vertical or inclined shaft to reach the water table, a sump in which the pump is placed, and a tunnel driven with its invert at a few inches or a few feet below the water table. The tunnel should be of such length and such exposed area under water level that the required draft causes a drawdown of only a small part of the head of the water table above sea level. In some parts of Hawaii, where the head may be 20 or more ft. above sea level, a drawdown of 2 or even 5 ft. is feasible; in thin lenses like those of the Marianas with a head of not over 2 ft., drawdown should be limited to a few inches.

Skimming Tunnels

If a tunnel of sufficient length is driven with its invert at sea level and is provided at its mouth with a weir so that its drawdown can be strictly limited to a few inches, and it overflows over the weir into a lined sump from which the yield is pumped, it is believed that the safe station capacity and regional capacity can be determined without doing serious initial damage. There is no need to gloss over the likelihood that the continuous capacity of many of the shallow water bodies of the islands may be very much less than might be desired and much less than the momentary amounts that were indicated by the early drilled wells in the weeks immediately following the landings.

There is a characteristic of these fresh water lenses which has its good and its bad points. That is the relatively large amount of water stored in the bottom part. This is one reason why in some instances quite a lot of water can be taken out at first without giving a true estimate of how much the replacement is. This storage is truly remarkable in amount and is really the reason for such extensive development and successful operation in Hawaii over these 60 years. In the Marianas these lenses certainly played their part in winning the war, but they are too thin to be relied on for any permanent regulation of water supplies.

In Hawaii the day of reckoning is well on the way, and water specialists in Honolulu are just now concerned with legislation which may establish a commission to study and control ground water use in the light of long-term community needs. This proposal is the culmination of studies begun in 1940, in which they have had the guidance and collaboration of Wells A. Hutchins, the eminent authority on the law of water rights and author of exhaustive reports on "The Law of Water Rights in the West" and on "The Hawaiian System of Water Rights" (7, 8).

Conclusion

The important points to remember in the safeguarding of island ground waters are:

1. The available ground water supply will not exceed some fraction, probably one-third or less, of the total rainfall on a given island.

2. Availability as potable water, with few exceptions, depends on the existence and stability of a Ghyben-Herzberg lens.

3. Stability of the lens depends on a suitable, moderate and regular permeability of the rock structure.

4. Freshness of the water and freedom from sea water intrusion depends on suitable rock texture, volume of fresh water flow and freedom from large openings to salt water.

5. Stability of the fresh water supply is greater with large flow, in islands of several miles radius, and with regularity of rainfall.

6. Draft of fresh water lowers the head and in some degree threatens the safe balance.

7. Water should be so drawn as to avoid undue disturbance of the preexisting conditions.

8. Prospects of getting fresh water and stability of the lens can in some degree be estimated from geologic and engineering considerations.

9. Reliable determination of the capacity of the well, station or district, because of the time required to reach a new equilibrium under variable rainfall conditions, will probably take several years, even with thorough and continuing measurements and study of the data.

10. Under any given conditions, the largest capacity and greatest safety from disastrous salt encroachment can be had by driving extensive skimming tunnels to secure the indicated draft with the least possible drawdown.

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Basic Concepts in Ground Water Law

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As the development of ground water supplies proceeds at an ever-accelerated rate, the need for adequate legislation to provide for their beneficial use becomes increasingly apparent. Not only in the West, but also in other parts of the country, there is a growing trend toward the use of ground water for irrigation. New industrial uses are appearing from time to time, and the use of ground water for air-conditioning is already receiving careful study by many states and municipalities (1). The uniformity of physical, chemical and bacteriological quality in ground water makes it particularly suitable for many purposes, and if one or more of these properties are considered important, ground water supplies may usually be developed more economically than surface supplies. This economy is particularly characteristic of water for domestic use and of supplies for smaller towns, cities and for many industries. Improved drilling techniques and pumping equipment have made deeper supplies more readily available.

On the other hand, legislation on the conservation and use of ground water has been slow to develop. Most of the states have enacted legislation for the sanitary control of ground water by state health departments. Legislation on its use and conservation, however, has developed more rapidly in the relatively arid West, where both surface and ground water problems are more acute. Approximately one-half of the western states have separate ground water statutes, and some measure of protection is afforded in the others either by the extension of statutes dealing with surface water or by interpretation of such statutes by the courts. In the East, only New York, New Jersey and Maryland appear to have made any appreciable progress in ground water control.

Several rather comprehensive studies of ground water law have been made, and legislation which may be characterized as quite progressive and effective has been passed by some western states. In 1934 the Association of Western State Engineers prepared a "Uniform Underground Water Law for Western States" (2). In 1943 the Subcommittee on State Water Law of the National Resources Planning Board formulated a suggested ground water statute to meet the needs of the western states (3). Members of the staff of the U.S. Geological Survey have reported important studies. Among them may be noted the comprehensive paper of Thompson and Fiedler (4) in 1938 and the more recent but briefer paper of McGuinness (5) in 1945. Of the state statutes which are avail-

able for study, those of New Mexico (6), enacted in 1931, and Kansas (7), enacted in 1945, may be taken as exemplifying present trends. The Kansas statute, in particular, was prepared after a most careful study of all of the material which has been cited.

A study of these statutes and recommendations reveals a rather striking uniformity in the inclusion of certain basic principles. This is not surprising, as, with one exception, they were developed for the relatively arid West, where water for irrigation is a prime essential, and other water problems are also common to many of the states.

It is the purpose of this paper to set forth a few basic principles which might be considered to be characteristic of good ground water legislation and to discuss them, not so much from the standpoint of what existing laws may be as from the viewpoint of what should be done to protect the public interest in a vital and essential natural resource. Being neither a hydrologist nor a lawyer, the author approaches the task with considerable trepidation but with the feeling that an objective treatment of this subject by one who has long studied it and has helped to fight its battles in his own state for many years might be worthwhile.

Accordingly, five basic concepts have been formulated, and they are preceded by a brief preamble. No attempt has been made to present them in statutory form. That is a problem for the trained legal mind. Furthermore, no originality is claimed for any of them, since all are to be found, in one form or another, in one or more of the references which have been cited. Taken together they are believed to constitute a solid core or framework on which the lawyer, the geologist and the engineer trained in ground water, working together and in the public interest, should be able to prepare ground water legislation which will adequately meet the present and future needs of the various states. It will of course be necessary to supplement and implement the material in such manner that the widely different problems to be encountered in various parts of the country may be dealt with. The concepts are presented together, since some of them are interrelated, and they will be discussed in the order given.

Some Basic Concepts

Some basic concepts that should be included in ground water laws are:

1. *Preamble,* to include the following:

a. A clear statement of the need for the adoption of the rule of appropriation as the guiding principle in the conservation and use of ground water.

b. A statement justifying the exercise of the police powers of the state in promulgating it.

2. *Concepts:*

a. The law should include a statement that all ground waters of the state are public waters and available for appropriation for beneficial use, subject to existing rights.

b. The law should include a statement that beneficial use shall be the basis, the measure and the limit to the use of waters included in the Act.

c. The law should be administered by a State Authority whose police powers are clearly and specifically set forth, and whose determinations of both water rights (used and unused) existing at the date of passage of the Act, and water rights acquired following its passage, would be subject to review by the courts.

d. The law should define vested rights, make provision for filing declarations covering such rights, provide for the reasonable recognition of common-law rights on the part of non-

users at the date of the passage of the Act, and require forfeiture of all rights by nonusers after a reasonable and stated period of time.

e. The law should specifically exempt from its provisions water for domestic use, except that the furnishing of information may be required by the State Water Authority.

There are three major rules which form the basis of most of the legislation on ground water rights:

1. English or Common-Law Doctrine

The English or common-law doctrine of water rights is based upon the ancient legal principle that the owner of land owns and has absolute right to the use of all that is found therein. Under it a landowner may withdraw percolating water (*Note:* for the definition of this term, see p. 996, "Classifications of Ground Water") therefrom at any time, to any extent, and for any purpose that he may wish. He may exercise his right in total disregard of the effect of his action upon the common water supply, or upon the rights of his neighbors to the same supply. He may even exhaust the supply which would otherwise be available for use by owners of other overlying lands and regardless of the beneficial uses which such other land owners might be making or of what injury would result to them. All this a landowner may do under this rule of absolute ownership without any liability whatever for any resulting injury to anyone else.

The common-law doctrine, as applied to surface waters, is also designated as the doctrine of riparian rights and the phrase "common-law doctrine of riparian rights" is to be found in almost all of the statutes dealing with surface waters and in the dicta of the courts interpreting them. Under this doctrine, as strictly interpreted, the owner of land contiguous to a stream is entitled to have the stream flow by or through his land undiminished in quantity and unchanged in quality except that any riparian owner may make whatever use of the water he requires for domestic and household purposes and the watering of farm animals. The doctrine has been generally modified to allow each proprietor to make such use of the water for irrigation of his riparian land as is reasonable in relation to the similar requirements of other proprietors of land contiguous to the same stream. The right does not depend upon use and therefore is not lost by nonuse.

It is important to note that the common-law doctrine which applies to ground water is not designated as riparian. It is, as has been previously stated, the right of absolute ownership of the water which may be captured on the land of the titleholder, and it may be used in any way he sees fit, in total disregard of the rights of others. This distinction should be carefully observed in order that further confusion in the development of sound ground water laws may be avoided.

The idea of the ownership of water underlying land is probably as old as the law of property itself. The old Roman law stated (8):

> *Portio enim agri videtur aqua. . . .* (Water is not an accessory of land but is a constituent part of it.)

2. American Rule of Reasonable Use

Briefly the American rule of reasonable use may be described as the rule under which a landowner may make only a reasonable use of percolating water underlying his land, having due regard to the equal rights of all other owners of land overlying the same common supply. It is like the riparian

rule in that the right to use water is derived from the ownership of land, but it recognizes that it is physically impossible for any landowner to make any use of ground water without to some extent diminishing the common supply to which adjacent land owners have equal rights. Under this rule waste of water, such as the discharge from uncontrolled flowing wells, may be prohibited. The so-called "Doctrine of Correlative Rights," which is a modification of the rule of reasonable use, was first designated in California and has since been followed in some other states. Under this rule, withdrawal for beneficial use by one owner may be restricted to that amount which does not prevent a similar withdrawal by his neighbor. If there is not sufficient water for the needs of all, this rule provides for the apportionment of the available supply on the basis of the area of land held by each—the rights of all owners of overlying land being correlative and co-equal.

This idea of correlative rights to the use of water dates back to ancient times. Plato (9) mentions its application in ancient Greece:

> . . . If there be a scarcity of water in any place, and the ground absorb rain without giving it some outlet, so that one lacks required water, he may dig upon his own land until he comes in contact with argil or clay; if he finds no water at that depth, he will draw off water from a neighboring tract for such quantities required and sufficient for the sustenance of his family. But if the neighbors themselves do not have enough for themselves, one turns to the Agronomists, who regulate the order in which each one must go each day to provide himself with water from his neighbors.

Plutarch (*op. cit.*) offers corroboration of the practice, giving a very definite suggestion of the idea of beneficial use:

> . . . If, after having excavated on their land to the great depths of 10 fathoms, they could not yet locate a water point, in this case they would be able to take from the wells of their neighbors a jug full of water containing six pots, two times each day, estimating with reason that it must be to help the need, not maintain idleness.

Mohammed made gifts of water a religious alm and sometimes a legal obligation. He who refused to give surplus water was gravely guilty in the sight of God (*op. cit.*).

3. Doctrine of Prior Appropriation

Under the doctrine of prior appropriation, as it has been developed, water is held to be public property subject to appropriation for beneficial use. It is based upon the time of use and the actual application to beneficial use, without regard to the owners of the contiguous or overlying land. It is a right to the use of water, not ownership of the water itself. In essence, it delegates to an early appropriator the right to continue to divert water from a source when the supply naturally available becomes insufficient for all those holding rights, *the first in time being the first in right,* as determined by the effective date of the appropriation. The origin of the principle of appropriation for beneficial use, as with the other rules of water rights, dates back to very early times. Many writers have termed it the "Roman Doctrine" (*op. cit.*), whereas others state that the common-law rule prevailed in ancient Rome and that the doctrine of prior appropriation, which undoubtedly is to be found in later Roman law, originated by judicial modifications and interpretations. It appears to have entered this country

by way of Mexico and has already exerted a profound influence upon the laws of water rights in the western states.

The common-law rule is still the rule that is most likely to be followed by the courts in most of the eastern and southern states and in some of the western states. As it is not founded upon use, in the absence of a statutory modification this right is not lost by nonuse. It is satisfactory as long as relatively small quantities of water are withdrawn, but it is obvious that it offers no possibility of any control to prevent overdraft of a ground water reservoir. It is interesting to know that the British Water Act of 1945, which has recently been summarized by Shaw (10), clearly indicates a tendency to depart from the common-law rule and emphasize the public interest in all natural waters. Part II—"Conservation and Protection of Water Resources"—opens with the following statement:

> Whenever the Minister decides that special measures are necessary for the conservation of water in an area he may make an order defining the area.
>
> In such an area no well or other work can be constructed for the purpose of extracting water from the ground and no existing well or work can be extended for the purpose of extracting additional water from the ground unless a license has been obtained from the Minister. Exceptions are made where the extracted water is to be used only for domestic purposes or where the construction is authorized by an enactment. Applicants who have been refused licenses are entitled to a hearing by a person appointed by the Minister.

Henry Berry, Chairman of the Metropolitan Water Board of London, makes the following comparison between the old doctrine and that contained in the new Water Act (11):

> . . . Private owners of land sink without let or hindrance wells on their land, and, having sunk them, draw water therefrom. Were it possible to draw water from beneath their own land only, there might be a greater show of right than appears; but such water is drawn from far and near and is used for the private purposes of the person or company sinking the well.
>
> Far different is it with any public water supply undertaking. Not only are they not allowed to sink wells without the consent of Parliament but all and sundry may oppose the proposal, and the Parliamentary path for such a public undertaking is indeed a difficult and costly one. Furthermore, the public water undertaking is hedged round with all sorts of conditions as to purity and limitation of output and the like. Naturally it would do nothing to affect the purity of its own water, but a private individual may leave a well in such a condition that it can readily pollute the underground water supply. It is therefore good to know that the government has declared that sectional interests shall be subordinate to the national interest and that there shall be control of private wells.

It is evident that the new act represents a radical departure from traditional practice. The language of the digest does not indicate that the doctrine of prior appropriation is recognized, but rather that something approaching the doctrine of correlative rights is contemplated. Authority for its administration in England and Wales is vested in the Minister of Health and in Scotland in the Secretary of State. Waste of water is prohibited and water conservation areas may be designated. Valuable powers are included to guard against pollution. It represents a step forward in the water supply history of Britain.

Although the rule of reasonable use and its extension as the rule of cor-

relative rights represent some advance over the common-law rule in the conservation of ground water, they have serious limitations when applied in practice. It is very difficult to determine what reasonable use is, particularly when the water is used for irrigation, because the acreage to which the water may be beneficially applied often exceeds the available supply. Its application may lead, and has led, to the overdevelopment of an area, because each holder of a correlative right will tend to use all that he needs. When the combined demands of all users finally exceed the total recharge, or begin to approach it, an apportionment must be made by legal means.

Perhaps the most serious limitation to the application of the rule results, however, from the right of a landowner to begin, at his pleasure, to develop rights long unused, perhaps with resulting damage to other users who may have made large investments which depend on the use of water. Such action is possible because a correlative right to the use of water, like a common-law right, is not lost by nonuse.

It is the judgment of those who have given most study to the problem, and who have observed the results which have been obtained by the application of the various rules, that the concept of prior appropriation will promote, to the greatest extent, the orderly and effective development of ground water supplies and will best protect the investments and undertakings which are dependent upon the use of such supplies.

Limitations of Prior Appropriation

The essence of the principle is the use of water in the inflexible order of priority of appropriation—"first in time, first in right." This principle, without question, offers the greatest protection to large investors whose appropriations are dependent upon an adequate supply of water. On the other hand, it inevitably leads at times to the use of water by a senior appropriator which would have been better used by a junior, and we are faced again with the fact that the rule of reasonable use must have a place in the administration of the doctrine. For example, some early appropriators may have been granted use of excessive quantities of water, yet these senior appropriators are under no compulsion to adopt efficient methods for its utilization. Again, a senior appropriator may employ inefficient and wasteful methods for transferring the water he has appropriated to the point of use so that the amount he actually uses may be only a small percentage of the amount which he appropriates. As a third possibility, a senior appropriator may be using water on lands of low productivity, where the yield may be considerably less per unit of water appropriated than it would be if a junior appropriator used the water on more productive land.

The solution to this problem of reasonable use would appear to be a realistic and equitable administration of the doctrine and its liberal interpretation by the courts. For example, the California Supreme Court has held that the use of an appreciable quantity of water for flooding lands for the sole purpose of exterminating gophers and squirrels in an area where the need for water is great is not a beneficial use under an appropriative right for irrigation (12). The Idaho Supreme Court sustained a finding by a referee in a trial court that the flooding of lands for the purpose of forming a

thick cap of ice to promote the retention of moisture in the soil well into the growing season was not a beneficial use (13). In an Oregon court case the court refused to sanction the use of 40 cfs. of water for the purpose of carrying off debris during the irrigation season, pointing out that this would result in depriving 1,600 acres of land of irrigation water (14). Samuel C. Weil, well-known authority on water law who has been previously quoted, in 1936 summed up the situation in the following words (15):

> At all events, adjusting uses that are now on hand seems to be getting more attention than additional developments. In terms of law, the moderating principles of correlative rights and reasonable use seem to be outstripping exclusive rights by priority of appropriation in general esteem. This is the impression which, it is believed, an observer obtains from the 50 years of water law here reviewed.

In the opinion of the Subcommittee on State Water Law of the National Resources Planning Board (3):

> There have not yet been enough tests of the authority to deny applications for appropriations to show the extent to which the courts would support state water administrative officials in their exercise of it. As the states more fully plan the utilization of their water resources with a view to meeting the requirements of multiple uses which advancing civilization will require, an elaboration and strengthening of the authority to control appropriation will inevitably develop. This Committee wishes to stress that the authority to exercise such control should not be allowed to lag behind the need for it. This will often require that the appropriation statutes shall be amended to require that appropriative rights shall be granted only when conditions, specified in greater detail, which are considered necessary to safeguard the public interest are met. The constitutions of some of the states specify that "appropriations shall never be denied." The type of statutory amendments mentioned would probably require amendment of some constitutional provisions. From a broad point of view, however, such amendments of the appropriations statutes might well be regarded as regulations of the granting of water rights and in no sense a denial of the right to appropriate water, and therefore consistent with such constitutional provisions.

A second defect in the administration of the rule of prior appropriation often lies in the lack of administrative authority. There appears to be a tendency in some states toward the routine granting of permits as they are received without adequate investigation and determination of the long-time availability of the quantity required. It cannot be too strongly emphasized that one of the most important factors in the successful administration of a ground water statute must be the utilization by the State Authority of a staff of competent hydrologists and engineers whose duty it would be to provide the basic data by which the statute could be administered.

A third problem common to the administration of water law results from the important part played by precedent in the development of legal principles by court decisions. As pointed out by Thompson and Fiedler (4), however:

> Subject to review by whatever higher court may have jurisdiction, a court is not necessarily bound by precedent if sound reason is presented for changing a principle. In making a decision a court is guided in part by the facts of the case as reported by witnesses on both sides, in part by the legal considerations presented by the counsel for each side, and in part

by its own knowledge of the legal princi-pls as well as other matters of knowledge and reasoning. It seems not unreasonable to expect that any judge or group of judges in making a decision upon some question of law arising *de novo*—for example, in one of the early ground water cases—might have reached a different conclusion if they had known some of the scientific facts and observations now available. The court has not always completely closed the door to a modification of principles. . . . We have emphasized these points because it is our belief that the present recognized unsatisfactory situation in regard to legal control of ground water is the result of inadequate knowledge or incorrect interpretation of certain natural laws and observed hydrologic conditions; that this situation has been perpetuated because stress has been laid on factors, which, although perhaps once important, now seem to be not nearly as important or applicable as some other things, and that there is hope of reaching a more satisfactory solution.

Lastly it has been felt by some that the adoption of the rule of appropriation in the place of the common-law doctrine and the exercise of the police power of the state in its administration would constitute a violation of that part of the 14th amendment to the Constitution of the United States, which states that no state shall "deprive any person of liberty or property without due process of law."

The question is a pertinent one, because, as has been stated, the common law gives to the owner title to all ground water underlying his land. As a matter of fact, as stated by Thompson and Fiedler (4):

> The Supreme Court of the United States has given a number of decisions which have interpreted the 14th amendment in such way as to give reasonable hope that it would not look upon the abandonment of the doctrine of riparian rights as the taking of property without due process of law, and has specifically recognized the power of the states to change the doctrine of riparian rights to the doctrine of appropriation.

In that connection they quote in part a decision of the Supreme Court, written by Justice Oliver Wendell Holmes:

> It sometimes is difficult to fix boundary stones between the private right of property and the police power, when, as in the case at bar, we know of few decisions that are very much in point. But it is recognized that the state as quasi-sovereign and representative of the interests of the public has a standing in court to protect the atmosphere, the water, and the forests within its territory, irrespective of the assent or dissent of the private owners of the land most immediately concerned. . . .

Classifications of Ground Water

Ground water may be classified in a number of ways. Two classifications occur most frequently in contemporary ground water law. One has to do with water moving in definite underground streams, and the other with so called "percolating water." In many of the statutes of the West, where the appropriation doctrine is applied to surface waters, it is also applied to water moving in definite underground streams, but in several of them percolating waters are still regarded as coming under the common-law rule. Consideration of some of the statutes referred to at the beginning of this paper reveals that there is no uniformity in the use of the term. In the suggested ground water statute of the Subcommittee on State Water Law of the National Resources Planning Board, ground waters are defined as "underground streams, channels, artesian basins, reservoirs, lakes and other bodies of

water in the ground." The Association of Western State Engineers added to this description the phrase: "moving in a definite lateral direction and having boundaries scientifically ascertainable." The New Mexico statute defines underground water as "the water of underground streams, channels, artesian basins, reservoirs or lakes having reasonably ascertainable boundaries," whereas the Kansas statute merely uses the term "ground water" without any classifying subdivisions.

Without going into an extensive discussion of the question, it is perfectly evident that the last, and simplest, statement is the best. Legal distinctions between definite underground streams, percolating waters and the like are based on a lack of understanding of hydrologic principles that existed at the time when the legal decisions were made. Fundamentally all ground waters are percolating. Essentially all of them occur in formations with reasonably ascertainable boundaries. Thus, in this sense there is only one kind of ground water and ground water law should apply equally to all of it.

Beneficial Use

The concept that "beneficial use shall be the basis, the measure and the limit to the use of water" is to be found in this exact wording in all of the codes which are being referred to save that of Kansas. In the Kansas statute the principle is definitely implied and the term "beneficial use" occurs many times through the text of the statute. In the author's opinion it is in this respect that the greatest difficulties in the administration of ground water laws are presented. As a single example, an owner holds an appropriation which was properly classified as beneficial use at the time it was acquired. Later technical developments make it possible for him to accomplish the same results with substantially less water, but only by making an additional investment. Should he be required to stand this additional cost in order to make the excess water available for use by junior appropriators? It seems evident that, in spite of the desirability of making the statute as specific as possible and of limiting the powers of the state authority, considerable flexibility is needed in its administration. Furthermore, there seems to be no doubt but that the concept of reasonable beneficial use must be introduced and adhered to, either by statute or by judicial interpretation.

Administration

Without a single exception, all of the codes with which comparison is being made provide that administration of the water statutes is to be on the state level. There are many reasons why this is so. In the first place it makes possible a centralization of records and a high degree of order and definiteness of rights. It makes possible the collection and dissemination of hydrological data by one trained staff of technicians, and it provides the best possible system for the collection and perpetuation of long-time records, the value of which will increase tremendously with time. It makes possible a better check of water wastes. It has proved to be workable, for it is employed in all but one of the western states. As an educator, the author cannot refrain from pointing out also that it permits a well-planned and state-wide program of education in which the press, radio, civic clubs and public schools could play a part.

A well-rounded program of legislation for water control and conservation is not achieved overnight. In several states, carefully prepared legislation has been presented year after year with completely negative results. In other states legislation which might be termed introductory has been enacted. It is understandable in view of the importance of the question that in some states the elected representatives of the people find themselves reluctant to delegate so much authority to the hands of a few. The fact that in many states there presently exists a multiplicity of state boards and commissions has been raised as an argument against state control, and there is emerging a definite tendency toward consolidating and reducing the number of such administrative units. It is believed to be true that in most of the states an appropriate state organization might be set up within an existing framework and eliminate this objection. After all, it becomes more and more evident that water conservation is merely an important phase of regional planning and that the units of such a program cannot be less than those established by the water itself. Such a program would not necessarily interfere with the efficient operation of existing local authorities, but, on the contrary, would effectively tie them together into an integrated pattern and supply the element of over-all planning so urgently needed for success.

Some states will necessarily have to work together to solve the problems of watersheds or underground reservoirs common to both. For example, northeastern Florida contains one of the greatest areas of artesian discharge on the American continent, yet a substantial part of the recharge area lies within the state of Georgia. Numerous similar examples could be cited, some of which are common to several states. It is obvious that only administration on the state level could hope adequately to cope with such situations.

Definition of Vested Rights

It is interesting to note that whereas all of the codes used for comparison specifically recognize vested rights, not all define them. The Kansas law is quite specific. Section I (d) reads:

> Vested rights means the right to continue the use of water having actively been applied to any beneficial use at the time of passage of the Act or within three years prior thereto to the extent of the existing beneficial use made thereof, and shall include the right to take and use the water for beneficial purposes where a person is engaged in the construction of works for the actual application of water to a beneficial use at the time of the passage of this Act, provided such works shall be completed and water is actually applied for such use within a reasonable time thereafter.

It is believed that vested rights should be recognized to the greatest extent consistent with existing conditions in the area as a matter of equity, and it is also believed that they should be clearly defined in the statute which is prepared. In those cases where existing vested uses are clearly excessive, adjustments should be made such that those uses shall be both reasonable and beneficial.

Exemption for Domestic Use

Four of the five codes used for comparison specifically exempt water for domestic purposes in almost exactly the words which have been used herein. Such water is not exempted in New Mexico, unless in the process of administration, for the code contains no

specific mention of such exemption. It is believed that this provision should be included in the ideal code from the standpoint of equity. It may be remarked in passing that the amount of water involved is so small that its exemption from the provisions of the act would probably not be significant. From the standpoint of public relations, the exemption of such supplies would greatly help to enlist popular support on the side of adequate water conservation legislation.

Effect of Draft

When water is withdrawn in any appreciable quantity from a well, either by pumping or by natural artesian flow, there is a drop in the head of water in the well and also in the formation from which the water is derived. This drop in head is greatest in the well itself and extends for a variable distance around the well. The area of this circle of influence depends upon a number of factors. It is to be remembered, however, that a drop in head does not necessarily indicate depletion of the supply, for even in the most permeable formations some drop in head is necessary if the water is to flow through the formation toward the well. As the withdrawal of water from a given formation increases, the head of the water normally decreases until a point of equilibrium is reached at which the total recharge to the formation just balances the total discharge of the wells. This point, if and when determined, should represent the maximum withdrawal from the formation without permanently depleting it. It might not represent the maximum "safe yield," however, because it might be below the economic limit of pumping. It would then not be reached in actual practice. This situation would, of course, represent the ideal in ground water conservation.

It is believed that a properly constructed ground water statute should specifically recognize these hydrological facts, and that reasonable limits should be set up within which the lowering of head by a junior appropriator would not constitute grounds for action by a senior. So many profitable ground water enterprises involve pumping that it should be permitted even if it means that occasionally a senior appropriator might be forced to resort to pumping water which formerly flowed to his land. It sometimes requires a long period of time to estimate with any degree of certainty the point of maximum withdrawal for any given discharge area, and it is for this reason that the collection of field data is so important in the administration of such statutes. It is evident also that the permissible lowering of head may vary widely in the various discharge areas in the same state. This provision is included in the suggested ground water statute of the Subcommittee on State Water Law of the National Resources Planning Board. The principle is also strongly recommended by the U.S. Geological Survey (4, 5), but it is not included in the text of any of the other statutes which have been considered. As all of the statutes provide that the Water Authority or State Engineer is authorized to set up regulations covering the beneficial use of water, it is possible that provisions embodying the thought stated may be included in such regulations.

Priority of Usage

Nowhere in the proposed statute has there been any mention or implication that the requirements of towns and

cities with respect to sources of municipal supply are a matter of primary concern and should be recognized in some way. Furthermore, in the various states there may be possible uses of water which are more beneficial than others and which should be given precedence. The Kansas statute specifically sets up a priority of use for appropriators, as follows: domestic, municipal, irrigation, industrial, recreational and water power. None of the other statutes attempt to establish priorities based on the nature of use.

The question is a legal one and there appear to be three solutions. One is specifically to exempt municipal supplies from the provisions of the act. A bill prepared by a State Committee on Water Resources and submitted to the legislature of the State of Florida in 1945 contained such a provision. The bill failed to pass. The second is to do as Kansas has done and set up a list of prior uses in which municipal uses would follow domestic uses. The third is to omit all specific mention of municipal supplies in the statute and to look to the courts for reasonable and favorable decisions in order that the present and future requirements of towns and cities for municipal water supplies will be adequately met. Perhaps the third alternative is the best. The right of eminent domain should assure towns and cities supplies adequate for present and future use, but if the increasing needs of a city should force a prior appropriator to curtail or discontinue his withdrawal, then such prior appropriator should be entitled to due compensation through a suitable action at law.

Sealing Abandoned Wells

No mention has been made of sealing abandoned wells, capping unused flowing wells, establishing works for the prevention of intrusion of salt water and so on. It is believed that although some such problems would be common to all the states, and although they may be and often are of greatest importance, they should be handled through the medium of suitable administrative regulations and should not be included in the statutes. It has been the author's experience over a number of years that the enactment of such legislation is made increasingly difficult in direct ratio to the amount of detail included in the statute. If the statute is based on the principle of appropriation of water for beneficial use, then the state authority should be able to formulate and enforce suitable regulations governing uses which are not reasonable and beneficial if, when and where needed.

Designating Areas of Control

Several of the statutes cited contain a statement to the effect that the State Engineer shall designate those areas and sub-areas in the state within which certain ground water regulations are to apply. The author is inclined to believe that such authority is implied in a properly drawn statute and that such provisions should be handled through the medium of administration.

In closing, attention is again called to the fact that success in such a program can best be achieved if lawyers, geologists and engineers work closely together in the preparation of such statutes. Through such co-operation the new statutes can best be fitted into the existing framework of state law, will most adequately meet the hydrological problems existing in the particular areas, and are most likely to receive sympathetic and equitable decisions at the hands of the courts.

It is hoped that the time is not far distant when all of the states may enact adequate legislation for the control and conservation of this most important natural resource.

Summary

It is suggested that in the preparation of legislation for the conservation and control of ground water the following be included:

First, a preamble setting forth the need for the adoption of the rule of appropriation for beneficial use as the guiding principle, and justifying the exercise of the police powers of the state in enforcing the Act.

Second, five basic concepts:

1. All ground waters of the state to be recognized as public waters and available for appropriation for beneficial use subject to existing rights.

2. Beneficial use to be the basis, the measure and the limit to the use of waters included in the Act.

3. Administration to be by a State Authority the police powers of which are clearly and specifically set forth and the determinations of which both of water rights, used and unused, existing at the time of the passage of the Act, and of water rights acquired following its passage, to be subject to review by the courts.

4. A definition of vested rights; provision for filing declarations of such rights; recognition of vested rights existing at the date of passage of the Act; and forfeiture of all rights by nonusers after a reasonable and stated period of time.

5. Specific exemption of domestic water supplies from the provisions of the Act, except that the furnishing of information may be required by the State Authority.

Acknowledgment

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Discussion

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In the semi-arid West there are many examples of communities which have knowingly overdrawn the local available ground water supplies. By placing no limitation upon the development of ground water and thus expanding in population, industry and assessed valuation, these communities have built up sufficient wealth to enable them to go longer distances to import needed water supplies. If there had initially been a law prohibiting such overdraft of ground water, it is quite likely that such communities would not have grown sufficiently to be able to procure the imported water supply. In some communities the same situation has involved surface supplies or a combination of surface and ground waters.

This situation, which has enabled many communities in Southern California to continue to expand and later to import water from beyond their local drainage areas in order to meet their expanding needs, should be considered when drafting a water code. Strict prohibitions of overdraft might prevent such socially and economically desirable results as have been obtained by many California communities, such as Los Angeles, Pasadena, San Diego and in general the cities of the Metropolitan Water District of Southern California and the San Diego County Water Authority, as well as San Francisco, Oakland, and the several East Bay cities.

Through the years this writer has attended a number of meetings called to consider drafting a ground water code for the state of California, primarily intended to prevent the overdraft of ground water basins. Largely because of the conditions described, no such code has ever been adopted by California.

Formulating Legislation To Protect Ground Water From Pollution

By Byron E. Doll

A paper presented on July 22, 1947, at the Annual Conference, San Francisco, by Byron E. Doll, Deputy City Engr., Huntington Park, Calif.

"WHY is legislation necessary?" and "What in the world could possibly pollute our ground water supplies?" are the first two questions the average layman asks of those seeking legislative protection of ground waters against pollution. Long-winded technical discussions usually evoke a shrug of the shoulders and an "Oh, well, it couldn't happen here!" But it can happen; it has happened; it will happen again unless something is done about it.

An article in the *Los Angeles Times* of Mar. 8, 1947, reports that the Attorney General of California filed an injunction suit against a chemical manufacturing plant discharging 280,000 gpd. of poisonous industrial waste liquid. The liquid seeped into underground water sources adjacent to Vernon, Calif., and endangered the drinking water of residents of Southeast Los Angeles, Maywood, South Gate, Huntington Park and adjacent Los Angeles County.

Here is one answer to the second question! But why did it occur? Why wasn't it prevented? Why lock the barn after the horse is stolen? Under existing legislation it is difficult, if not impossible, to take preventive action. Only after the damage has occurred are state agencies empowered to act.

Water is the life blood of California—the second largest state in area, the third largest in population. Without water, California's industry, population and agriculture would cease its recent rapid expansion and rapidly diminish in volume to relative insignificance. Every drop of water, therefore, must be conserved and put to some beneficial use.

Conservation means the preservation of the quality as well as the quantity of water. It means the prevention of contamination from sewage, liquid industrial wastes or other sources, as well as the utilization of flood waters to replenish the ground water supply, instead of permitting them to be wasted to the ocean. Conservation in this broad sense is necessary for the continued development of California. Adequate quantities of pure water are essential to public health, safety and welfare, to a continued productive agriculture, and to a continuing and expanding industrial development.

Although conservation is essential to every part of the state, the wide variations in climate and topography present different problems in different regions. Even the pollution of water by industrial wastes, a problem which exists throughout the state, is different in different areas, and requires entirely different methods of control.

Surface waters are the principal problem in northern and central California. Along the coast at Monterey, San Diego and San Francisco, pollution of the salt waters has rendered them unfit for industrial and recreational use. In southern California both surface and ground water supplies have been polluted. As ground water basins are the prime source of supply in southern California, this problem is most grave in this area.

Ground Water Supplies

In all probability, the earliest means of obtaining water not naturally available was by digging wells and making use of natural ground water supplies. In arid and semi-arid regions, ground water is still the primary source of water supply. Despite the development of the Owens Valley Aqueduct by Los Angeles, the Colorado River Aqueduct by the Metropolitan Water Dist. of Southern California, and the water system of San Diego—all of which utilize surface waters—ground water is still the largest and most important source of water in southern California. It is not only the sole source of water supply for many farms, industries, communities and cities, but is also an important source of supply for Los Angeles and many of the member cities of the Metropolitan Water Dist. of Southern California. The conservation of this supply by safeguarding its quality is a matter which vitally affects industry, agriculture and the general public.

Industrial waste disposal and its relationship to ground water resources acutely affect the future development and growth of five southern California counties: Los Angeles, Orange, Riverside, San Bernardino and Ventura. Since the industrial development and waste disposal problems of Los Angeles County roughly parallel those of the other counties, a careful examination of its problems will be indicative of conditions elsewhere. There are, however, two important differences which must be borne in mind: (1) the industrial development in Los Angeles County, which contributes to its water supply problems, is much more intensive than in any of the other affected counties; and (2) practically all of the ground water basins supplying Los Angeles County with water lie within the county boundaries, whereas the Santa Ana River Basin lies in San Bernardino, Riverside and Orange Counties.

Los Angeles County is divided into five separate and distinct physiographic areas:

Antelope Valley, the southwestern portion of the Mojave Desert lying north of the San Gabriel Mountains, is comparatively undeveloped industrially, has a relatively small population engaged primarily in agriculture and will be mentioned only in passing.

The San Gabriel-Sierra Pelona Mountains, lying about thirty miles from the sea, are the source of the Los Angeles and San Gabriel Rivers and of most of their tributaries. These mountains separate the Antelope Valley from the coastal watershed.

South of the San Gabriel Mountains lies a chain of structural valleys, of which the San Fernando and San Gabriel are the largest, and the coastal plain. The valley section and the coastal plain area are separated by a range of sedimentary hills lying about eighteen to twenty miles from the ocean.

Underlying the valley section and the coastal plain are the three main ground water basins: the San Fernando, San Gabriel and the Coastal Plain, and 25 sub-basins. The ground

water basins are prehistoric stream beds and lakes now consisting of water-saturated gravels and situated at depths varying from a few hundred feet to more than 1,500 ft. below the surface. Even the rivers are upside down, and although they have large flows, most of them are unseen and flow through the porous gravels lying below the surface of the ground. Because these gravels are so porous, industrial wastes which enter them may pollute large quantities of water before detection. Contamination may become serious before it is noted, due to the slow rate of travel of the ground water through the underground gravels. Water in a basin so polluted may remain unpotable, unsuitable for industry, or unusable for agriculture for years, even after the source of pollution has been eliminated. Yet in this valley and coastal plain of Los Angeles County are its vast underground reservoirs of water. As Loren Blakely has aptly stated: "We are living on the roof of our reservoir," for concentrated in these areas are most of Los Angeles County's 3,440,000 population inhabiting her 45 incorporated cities and 100 unincorporated communities, her 303,000 cultivated acres and her more than 10,000 industries.

Industrial Wastes

The industries are of every imaginable type; their wastes are just as varied as the 1,001 tales of Scheherezade's *Arabian Nights*. The wastes are of every conceivable nature; all kinds of acids and alkalies, phenols from plastics manufacturing plants, heavy metals, including hexavalent chromium from plating plants, greasy wastes from canneries, packing plants and wool processing plants, boron from fruit packing plants, saline and oily wastes from oil wells and refineries, as well as wastes from railroad car yards, soap factories, paint factories, breweries, paper mills, gas plants and butadiene plants, and waste water from cooling processes.

Wastes from many of these plants are discharged in such a manner as actually or potentially to pollute the ground water. The reason? At times, overloaded sewers; at others because local officials have required discharge of wastes likely to damage the sewers into sumps, washes, arroyos or sewer wells. Even the great "Queen of the Angels," Los Angeles, cannot agree with herself. Officials of the Dept. of Water and Power have been doing everything within their power to prevent the discharge of wastes in such a manner as to pollute the ground water supplies, whereas the Bureau of Maintenance and Sanitation has required many industries to disconnect from sewers and discharge wastes which are not harmful to storm drains and do not have excessive turbidities into storm drains discharging into the Los Angeles River, where these trade wastes may enter directly into ground water supplies. Certainly this is a gem of inconsistency and may be one reason why we refer to cities in the feminine gender.

On occasion, local officials have been more anxious to attract a new industry than to require adequate pre-treatment of wastes even when discharged into sewers. For economic reasons (such as lower taxes), however, much of this industrial development has taken place in unsewered areas. Much of it, as has been mentioned before, has taken place in areas where sewers were already overtaxed. Under such conditions, the liquid industrial wastes have been discharged into sumps, into storm drains or directly into stream channels with no thought or regard

for the possible effect upon ground waters. At times, in sewered areas, when the nature of the industrial wastes would have a deleterious effect upon the sewer system or upon treatment processes, industries have been forced by governmental officials to forego the use of sewers and to dispose of their wastes in the same manner as industries in unsewered areas. The mere discharge of industrial wastes into a sewer system, however, with subsequent treatment at a sewage treatment plant, is no guarantee that pollution of ground water supplies will be avoided. Not all of southern California's sewage treatment plants discharge into the ocean. Many of them discharge into arroyos or into the rivers. Despite their size, large quantities of water are carried by these rivers, even if in subsurface flow, and much of this water is recovered by wells located adjacent to the banks of the river.

Typical of these situations is the Montebello incident of which much has been written. Briefly, wastes from a small plant manufacturing a weed killer, commonly known as 2-4-D, were discharged into the sewers of the city of Alhambra. At the Tri-Cities Sewage Treatment Plant, serving the cities of Pasadena, Alhambra and South Pasadena, Calif., these wastes were diluted with 12 mgd. of sewage, and, after receiving complete treatment, were chlorinated and discharged into the Rio Hondo about one mile above the Whittier Narrows in an area of rising water. At this location the flow from the Main San Gabriel Basin to the Coastal Plain is forced to the surface of the stream channel for a short distance before again resuming its underground travel. Fortunately, these wastes did not enter the Main San Gabriel Water Basin, or the damage would have been much more serious. That, however, is small comfort to the South Montebello Irrigation Dist., for within 17 days the first of its wells was affected. Within a short time 11 wells serving 25,000 people were affected. This occurred in June 1945. In June 1947 treatment of water from these wells was still necessary to make the water potable.

In 1946 the Los Angeles Dept. of Water and Power surveyed a portion of the Los Angeles River Channel and found approximately 125 locations where industrial wastes were being discharged into the river. Flows varied from small amounts up to several cubic feet per second, and consisted of phenols, caustics, acids, soaps, oils, greases and similarly appetizing items. Below Washington Boulevard, where the paved channel of the Los Angeles River ends, these wastes percolate into the upper ground water strata. According to the State Engineer's office, these industrial wastes are considered responsible for the abandonment of at least two polluted wells.

In the Long Beach–Signal Hill–Compton area, wells have been polluted by wastes from oil recovery and refinery processes. Such pollution has also been reported in other areas.

Wastes variously reported as phenols and cedar oils, the latter from a battery manufacturing plant, have allegedly caused the abandonment of wells in the Vernon–Huntington Park area in about 1917. Another reported, but unconfirmed, abandonment of a shallow well in the Vernon area was due to kerosene. Wells in the Los Angeles Griffith Park are known to have a chromium content higher than the maximum permitted by U.S. Public Health Service "Drinking Water Standards" (1), due to the discharge

of wastes from aircraft plants in the Burbank area. Instances of actual or potential pollution have also been reported in other southern California counties.

Although the problems of southern California have been discussed at some length, the problem is by no means local, existing also in other sections of the country where ground water is extracted from saturated sands or gravels. A large factory near Phoenix, Ariz., is reportedly obtaining its water supply from several wells and disposing of waste products in sewer wells. This practice may conserve water, but it is strongly reminiscent of the old time privy and well on the farm. The well may never run dry, but the quality of its water must certainly be affected. The author has also been told of water supplies polluted by waste products from citrus processing plants at such widely separated points as southern California and Florida.

Menace of Pollution

Even though such wastes have not actually polluted water supplies, their disposal in such a manner constitutes an ever-present threat to one or more of the following:

1. Public health, safety and welfare
2. Aesthetic considerations
3. Potability of water supplies
4. Suitability for agricultural uses
5. Suitability for industrial purposes.

Such a threat is serious. Surface reservoirs and conduits would be protected from such pollution by every means at the water department's command, even though their capacity is but a fraction of that of the ground water basins in Los Angeles County alone. It has been computed that it would take the combined flow of the Owens Valley and the Colorado River aqueducts over five years to fill the ground water basins of Los Angeles County.

The comparison of ground water basins to surface reservoirs and the likening of ground water flow to pipelines and surface streams is not strictly accurate. Wind action, wave action and currents, both vertical and horizontal, are found in surface waters but not in ground water basins. Nor does turbulence or mixing action occur in ground waters. The velocity of surface flow is much greater, and impurities introduced into surface waters are rapidly dispersed and diffused throughout the entire body of water, with a consequently greater dilution. Pollution is soon noted and traced to its source with comparative ease and speed.

In ground waters, however, it has been found that, due to the low velocities and the lack of turbulence, pollution is not dispersed but tends to travel in a narrow band with but little dilution. As it will therefore be noted only in wells directly in the path of flow, it may be years before such pollution is discovered, and it would be extremely difficult if not impossible to trace it to its source. Even though the source were located, and the pollution halted, however, many years might elapse before the basin would again be suitable for use.

Just as the emphasis in public health measures has progressed from the attempt to stop epidemics after they have started to preventive medicine, so must the water works man's concept of corrective action change to preventive action. Concerted action has accomplished the elimination of many cross-connections between water supply systems and polluted water supplies. Present-day standards of purity can and must be applied to our ground water resources. This serious prob-

lem deserves a reasonable and rational approach and a prompt solution to protect the interests of the public, of agriculture and of industry.

Legislative Protection

It has been made clear that the ground water supplies of California are in need of protection from pollution by industrial wastes. Any discussion of the existing laws on the subject lies more within the field of the lawyer than the engineer. It is felt, however, that existing laws are inadequate. Whether the fault lies with the law or with the enforcing agencies is immaterial. The end result is the same. It is believed that anyone closely associated with the problem will agree that results to date have been unsatisfactory.

It should be noted that the California Water Code declares it to be the policy of the state that all water, both surface and underground, is the property of the people of the state, that all waters shall be developed for the greatest public benefit, and that use for domestic purposes is the "highest" use, and the next highest is for irrigation. Consequently, discharge of industrial wastes into ground waters in such a manner as to render them unfit for either domestic or agricultural use is contrary to the policy of the state.

Because of this policy, as well as for other practical considerations, it is not believed that the pollution of ground water should be handled as a separate problem. Nor should the approach to a solution be limited solely to the pollution of water supplies by industrial wastes. The more logical procedure is the prevention of pollution of all waters, surface and underground, fresh and saline.

In the last session of the California Legislature, House Resolution No. 27 appropriated $100,000 for an Assembly Interim Committee of nine members to study the problem of the pollution of the state's waters. It is interesting to note that three members are from the San Francisco Bay Area, four members from the southern California area and one each from the Monterey Bay Area and the San Joaquin Valley Area. The portion of the Resolution giving the committee its instructions is of general interest:

WHEREAS, The problem of water pollution resulting from disposal of industrial wastes and sewage is a subject of vital concern to the entire State of California; and

WHEREAS, It is a problem requiring exhaustive analysis, intelligent treatment and widespread education of all concerned; and

WHEREAS, A preliminary Draft of Legislation to Control Pollution of Water Sources has been prepared, which document is considered to be too far-reaching in its effect and too narrow in its adjudication and administration to warrant the support which should be given to a fair and impartial effort to solve the problems of industrial waste; and

WHEREAS, In the interests of the welfare of the public health, agriculture, industry and all others concerned, it is deemed advisable that further study be given to the subject of this Resolution; now,

THEREFORE, BE IT RESOLVED by the Assembly of the State of California, as follows:

The fact-finding committee on water pollution is hereby created and authorized and directed to ascertain, study and analyze all facts relating to the procedure designed to prevent pollution of:

1. Underground water flows, particularly in the semi-arid and arid sections of the State; and

2. Surface streams in the sections of the State where there is continual surface runoff from the watershed; and

3. The lower reaches of the principal river systems, and the coastal bays and shores;

Including that not limited to the operation, effect, administration, enforcement and needed revision of any and all laws in any way bearing upon or relating to the subject of this resolution, and to report thereon to the Legislature, including in the reports its recommendation for appropriate legislation.

Industry, agriculture, governmental agencies, public health officials, chambers of commerce, water and sewage works operators all joined in their support of this resolution to obtain a satisfactory solution to a common problem. The committee will welcome the support of, and invites constructive suggestions from, all parties interested in the prevention of the pollution of the states' waters.

In the seven states controlling industrial waste disposal through boards or commissions independent of the state health departments, effective control is obtained with the co-operation of industry to obtain the greatest good for the greatest number. To obtain the greatest good for the greatest number is a fundamental policy of our country and must govern the control of industrial waste disposal and the prevention of the pollution of water.

To obtain adequate protection of water supplies for domestic, agricultural and industrial uses and at the same time to safeguard other important interests of the people, agriculture and industry, it is believed that California should be guided by experience gained in other states.

It is believed that legislation, to be adequate, should provide for:

1. Formation of a State Water Authority with the duties and functions of planning, administering and enforcing the conservation, development, utilization and protection from waste and pollution of all water resources of the state, in order to attain and protect the state's expressed policy favoring the development of water resources for the greatest public benefit.

2. The protection of the interests of the public, agriculture and industry requires representatives not only of water supplies, agriculture, industry and local enforcement agencies, but also of the State Engineer's Office and the Departments of Natural Resources, Agriculture and Health.

3. Required enforcement by local political subdivisions, where a local watershed or ground water basin lies within its borders.

4. Enforcement by a local entity, where a watershed or ground water basin encompasses more than one local political sub-division, unless such a local coalition fails to act, whereupon enforcement should be by the state authority.

5. Enforcement and the granting of permits by the lowest local agency which complies with state standards; with planning and supervision on a state-wide level.

Acknowledgment

The ideas and content of this article are not claimed to be original, but are the result of many conferences with water works men interested in the problem and are presented merely to stimulate interest and discussion in the problem. Practical limitations do not permit the giving of credit to all to whom it is due. It is hoped that this brief thanks will suffice.

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Developing Standards for the Protection of Ground Water

By Ray F. Goudey

A paper presented on July 22, 1947, at the Annual Conference, San Francisco, by Ray F. Goudey, Cons. San. Engr., Truesdail Labs., Inc., Los Angeles.

It is obviously impossible to develop general standards for the protection of ground water, although areas having common problems can well afford to organize and solve them on their own merits. The problems of ground water protection cannot be divorced from those of stream pollution control because percolating waters, whether natural or artificial, create ground water, which in part (either directly or indirectly) may again reach surface streams. In some of the western watersheds, surface water may be diverted for irrigation, seep into the ground and rise again as surface water for as many as five cycles of re-use.

Water is a national resource of inestimable value and is subject to a wide variety of public uses, some of which are obviously incompatible. Ordinary uses include water supply for: (1) human beings, animals and industries; (2) irrigation and power; (3) recreational use, including fishing, hunting, swimming, boating and picnicking; (4) commercial fishing, including the raising of shellfish; (5) maintenance of animal and aquatic life in streams; (6) disposal of domestic and industrial wastes; and (7) navigation.

Common sense has dictated that the best waters be allocated for domestic purposes. Although it is also obvious that polluted waters can never be restored to their pristine purity, it is equally evident that they should not therefore be abandoned to further reckless pollution. In other words, conservation is a common plank on which all interests must agree, and any decisions which are arrived at by democratic means and which are for the best interests of the greatest number of people, should be faithfully recognized by all.

Ground water is usually restricted, first to domestic, industrial and irrigational uses, and, second, to conveying sewage and industrial wastes underground. The conflict of uses is sharper in dealing with ground water than with surface waters. Careful consideration must be given to controlling mineral and organic pollution in ground water basins in regions where such water is the lifeblood of a community. The field is much broader than would be indicated by the usual concern over toxic substances menacing health, for the economic aspects of a deteriorated domestic, industrial and irrigational supply are of tremendous concern.

State Control Agencies

Stream pollution control has been undergoing a radical evolution, a study of which suggests valuable hints which

might be followed in ground water protection. It should be recalled that most state health departments in the country were organized in the 1860–1870 decade, chiefly to combat the stream pollution which resulted from the rapid construction of sewers following their introduction in 1847. The control was aimed at protecting people from water-borne diseases transmitted by sewage and to control the discharge of toxic wastes which might menace public health. These are still the ruling doctrines in one-third of the states of the country, where industrial development has not become too great a problem or where sharp conflicts among the multiple uses of water have not arisen. Even in these states the general health laws have been sufficiently broad to regulate gross instances of pollution from mine and mill wastes, silt from placer mines, oil brines, refinery wastes, paper mill wastes and sugar beet wastes. Under general state powers, limits have been set to the discharge of TNT, phenol and cyanide wastes. State departments of health have been successful in abating gross nuisances and in maintaining satisfactory oxygen balances in streams.

In most of the states relying only on general laws, there has been a steady increase in the powers of fish and game commissions. In Arkansas, California, South Carolina and possibly other states, more stream pollution control power has been delegated by the states to their fish and game commissions than to their health departments. Gradually other conflicts have arisen, involving such state departments as those of public works, highways, commerce, conservation and agriculture. These conflicts clearly indicated that stream pollution control involved more than just the old-line jurisdiction of health departments operating under general laws.

To fill the need arising in the most industrialized states, in which problems occasioned by the multiple use of water were becoming more and more critical, nine of the states extended their public health laws to create strong sanitary engineering departments, or their equivalent, and made them the administrative agencies for strong advisory or control boards, which in one way or another represented all of the interests directly involved. Representation on these boards has been varied. In six states—Indiana, Michigan, Minnesota, Pennsylvania, Washington and Wisconsin—the advisory boards were made up of the heads of state departments, such as the attorney general, and the heads of the departments of agriculture, conservation, fish and game, health and public works. All of the states, of course, did not organize their boards in the same pattern.

Nothing but praise can be given to these states in the excellent stream pollution control work carried on so far. It has included a field far more extensive in public welfare than could have been accomplished without such legislation. One state—Oregon—has an advisory board for its state sanitary engineer in the health department, and this board is made up of five citizens appointed by the governor with no representation whatever from any of the state departments. Two states bolster up their health department's engineering divisions with boards which not only include heads of various state departments but also have outside representation. In Illinois a representative from industry serves on the advisory board, and in Tennessee two representatives of industry and two

representatives serving municipalities serve side by side with the heads of state departments. The trend is in the direction of giving representation to industry, municipalities and citizens at large, in order to represent all of the major factions in the stream pollution control field and also to avoid the drawing up of specific standards for general guidance.

Four states have decided to take the administration of stream pollution control entirely out of the hands of their health departments and have created stream pollution control boards with their own administrative agencies. In Connecticut a state water commission consisting of three men appointed by the governor has complete jurisdiction over all stream pollution control work, including control of industrial wastes and the power to review the disposal of sewage into streams as worked out by the state health department. This commission likewise has no specific standards, but does prohibit the discharge into streams of any cyanide wastes which are equivalent to a practical limit of 2–3 ppm., which is the sensitivity of the cyanide test.

In Louisiana a very strong stream pollution commission representing the Attorney General, and State Departments of Agriculture, Conservation, Commerce and Industry and Health, has its own administratiwe agency, which is independent of the Health Dept. This commission has undisputed charge of stream pollution control, including aspects affecting health, public welfare, fish and aquatic life, and the power to enforce specific standards after investigation of particular violations. The orders controlling paper mill wastes and disposing of oil field wastes are particularly effective.

The states of Virginia and West Virginia have also set up state water control boards outside the departments of public health. These boards are composed of citizens-at-large and have their own administrative agencies. The good work done in these two states is silent testimony that this type of control is likewise effective.

Interstate Boards

There are four examples of stream pollution control work carried on by groups of states in which common problems require common effort. It is necessary to study these in order to appraise fully the stream pollution control field in the United States:

Tri-state Compact

The states of New York, New Jersey and Connecticut created an Interstate Sanitation Commission consisting of five members from each state to protect common tidal waters from gross pollution. This commission fixed some rather general standards—such as for the removal of all floating solids, the removal of 60 per cent of suspended solids and the maintenance of at least 50 per cent oxygen saturation in the receiving waters—in order to protect tidal waters for industrial use, navigation and fish life.

Interstate Commission of the Potomac River Basin

Those parts of the states of Pennsylvania, West Virginia, Maryland, Virginia and the District of Columbia lying within the watershed of the Potomac River were organized into the Potomac Conservancy District. Three members from each state form the Interstate Commission of the Potomac River Basin, which is charged with the duty of clearing up existing pollu-

tion and preventing such future pollution as will be detrimental to the public welfare. This commission has classified streams but has not developed specific standards.

Delaware River Basin Interstate Commission

The Delaware River Basin Interstate Commission, consisting of 23 members representing those parts of New York, New Jersey, Pennsylvania and Delaware which lie within the drainage area of the Delaware River, have probably done the most advanced work on stream pollution control of any agency so far. This board is made up largely of legislators, with very little representation from any state departments.

The entire watershed has been divided into four zones, representing four degrees of recognized pollution, with limits on the biochemical oxygen demand, dissolved oxygen and coliform bacteria, and on the floating solids, suspended solids, grease and sludge which may be discharged by industries while still maintaining each type of water for the uses allocated to them. The best waters are suitable for recreation, bathing, agriculture and stream life, and yet, after appropriate treatment, may be suitable as sources of water for domestic purposes. The poorest waters, on the other hand, which are suitable only for navigation, recreation and industrial supplies, must still be good enough for commercial fishing. This is a relatively high standard for a "poor" water. It is questionable if any commission should go farther than this in the classification of streams and in setting standards. The method of approach used by this commission appears to be most successful.

Ohio River Valley Sanitation Compact

The states of Illinois, Indiana, Kentucky, New York, Ohio, Pennsylvania, Tennessee and West Virginia (except that West Virginia's participation depends upon Virginia's signing) have already agreed, for the protection of health and the preservation of Ohio River waters for all legitimate purposes, to maintain such standards that, with appropriate treatment, the waters may be used for domestic and industrial purposes, and the streams themselves will be sufficiently clean to permit recreational use in fishing and aquatic activities. Each state agreed that it would so use the waters that the pollution leaving the state would not be greater than that entering the state. This compact specifies that there can be no single standard applicable throughout the watershed, due to such variables as size, flow, location, character, self-purification and uses of waters within the district. For some time these states have also been reporting the times of phenol spills, so that water companies could avoid taking water containing excessive amounts of phenol.

It is noteworthy that the state of New York belongs to three of the four interstate compacts, and that the state of Pennsylvania belongs to another group of three compacting states, which evidently proves that this method of attack is both sound and successful.

Definitions

In reviewing all of the available stream pollution control laws, only two specific references to protection of ground waters were found, in the laws of Pennsylvania and Washington. A blending of both definitions of "water" should be made, it is felt, to obtain a

definition broad enough to include ground water.

In Pennsylvania law water is thus defined: "Waters of the Commonwealth shall be construed to include any and all rivers, streams, creeks, rivulets, lakes, dammed water, ponds, springs and all other bodies of surface and underground water, or parts thereof, whether natural or artificial within or on the boundaries of this Commonwealth" (Act 117, dated May 8, 1945). In Washington: "The Commission shall have jurisdiction to control and prevent the pollution of streams, lakes, rivers, ponds, inland waters, salt waters, water courses, and other surface and underground waters of the State of Washington" (Sec. 10, Chap. 216, Laws of 1945). Several states include the word "drains" in their definitions of "water."

There appears to be a very wide divergence on how to define the word "pollution." A composite definition might read:

Pollution shall be construed to mean the discharge or deposit of sewage, industrial wastes or other substances; or the alteration of water quality by natural or artificial means, including importation of water, water diversions or overdraft, which affect surface and ground waters under such circumstances that the manner or quantity of noxious and deleterious substances renders so unclean, contaminated or impure any surface or ground waters within or on the boundaries of the state as to be harmful or inimical to the public health, or to the health of animals, fish and aquatic life; or renders such waters unsuited after reasonable treatment for use at the present or any future time for domestic, irrigational and industrial purposes; or is harmful or inimical to the public welfare and conservation where mining, recreational and other public uses have been established.

Principles of Control

Additional lessons to be gleaned from a review of stream pollution control legislation which have a direct bearing on protection of ground water supplies are:

1. The size of an area in which ground water protection is to be practiced should include the entire drainage areas in which there are common interests in the use of water. Such an area may be less in size than a state or may contain parts of several states.

2. A commission should be established for each common area agreeing to practice pollution control. Such a body should have its own administrative agency and include representatives of agriculture, industry, municipalities and citizens-at-large in order to represent all types of water users.

3. Such a commission should have full power to review all discharges of sewage into streams or ground water, even though they have been approved by the state department of public health.

4. The commission should have full power to plan, investigate, conduct research, classify waters, evaluate uses, provide measures for public and private financing of pollution control works, and be given such enforcement powers as are acceptable to all interests concerned.

5. The commission should establish standards of cleanliness or degrees of permissible pollution by organic and mineral constituents, much as has been done by the Delaware River Basin Interstate Commission and the West Virginia State Water Commission. For example, in the Delaware River

Basin the minimum requirement No. 5 for Zone 1 Waters holds that:

> Such effluent shall be sufficiently free of acids, alkalis and other toxic or deleterious substances that it will not create a menace to the public health through the use of the waters of the Delaware River for public water supplies, for recreation, bathing, agriculture and other purposes; nor be inimical to fish, animal or aquatic life.

In West Virginia specific limits have been placed on coliform bacteria, dissolved oxygen, biochemical oxygen, demand pH, fluorides, chlorides, phenolic compounds, iron, color, turbidity, sludge deposits and other conditions for four types of waters. Class AA waters are excellent for sources of water supply, fish habitat and recreational use. Class A waters represent a good source of water supply and are good for fish habitat and recreational use. Class B waters serve as sources of water supply if given complete and auxiliary treatment; are poor as fish habitats or for recreation. Class C waters constitute unsatisfactory sources of water supply and are unsuitable as fish habitats and recreational waters (1). It is apparent that these standards, although specific, are below those being enforced on the Delaware River Basin.

The Michigan Stream Control Commission has two requirements that involve mineral pollution: items "f" and "g" as stated in the Meeting Agenda dated May 15, 1946, which read: ". . . control salinity or other chemical components within limits which will maintain suitable quality of water for industrial or domestic use. Elimination of substances toxic to humans, fish, aquatic life and wild life."

6. The control commission should be hesitant in adopting specific standards for general application, but, if they are found necessary after investigation, should issue its recommendations or orders in such terms as can be readily understood, based on plant production. Three paper mills in Michigan operate under a restriction prohibiting more than 0.25 lb. of suspended solids per 1,000 gal. of waste (an amount equivalent to 5 lb. of suspended solids per ton of product, based on a discharge of 20,000 gal. of waste per ton). In Maine a court ruled: "Until further order of court, Brown Co. will effectively provide that it will not deposit in said Androscoggin River during any one week sulfite waste liquor resulting from the manufacture of more than 3,000 tons of finished sulfite pulp."

7. The primary object of a stream and ground water pollution board would be to evaluate the uses to which water may be put and to allocate such uses to the greatest possible public good, recognizing the economic and conservation factors. Individual problems should be decided on their own merits, and no practices should be allowed which in principle cannot be extended to all.

Ground Water Protection

In any ground water investigation, it is necessary to differentiate natural changes in quality from those induced by artificial means. The natural quality of ground water varies with each watershed and reflects the combined factors of rainfall on porous areas, stream flow, drainage waters, and the changes which occur in quality as the ground water journeys through geological formations of different types. There may be marked seasonal variations depending on the variations in rainfall.

Even greater changes in water quality, to the extent of actual injury, may occur through a great variety of man-made interferences, such as:

1. The discharge of sewage and industrial wastes into streams and cesspools.

2. The use of water for irrigation, which returns underground about 25 per cent of the water applied, with a concentration of twice the calcium, magnesium and alkalinity, and a concentration of sodium, sulfates and chlorides four times higher than in the applied water. This ground water, when pumped, will have a much higher sodium ratio than the originally applied water.

3. On two known occasions, the use of nitrogenous fertilizers and sulfur compounds for soil correction has adversely affected public water supplies and has increased slime growths in distribution systems.

4. The development of new irrigation areas increases the mineralization of ground water, due to the flushing of dissolved salts of the soil and geological formations between the water table and the surface.

5. The importation of water having a high mineral content, whether used for domestic or irrigational purposes, greatly increases the mineral content of the underground water where such waters commingle.

6. The exportation of surface water out of the watershed has often increased the mineralization of the ground water.

7. The overdrawing of ground water or the mining of it not only stops all opportunity to dilute industrial wastes reaching the aquifers but lowers the hydraulic gradient to the point at which water from other basins of different quality, or salt water from the ocean, may replace the lost water.

8. Construction of dams for the impounding and evaporation of surface waters, the construction of drainage ditches and the toleration of vegetation along waterways and channels increase ground water mineralization.

9. Disposal of oil well brines into oil-bearing strata and carelessness in sealing abandoned wells have several times caused serious pollution over wide areas in several states. Pressurizing disposal wells has caused low grade oils and brines to penetrate deep valley water-bearing strata.

10. Water basins, once salted out, require time and excessive quantities of water to recover.

Effects of Pollution

Ground water injuries may affect domestic, irrigational and industrial supplies in a number of ways:

Domestic Water Supplies

1. Execessive bacterial contamination having both health and sanitary significance may cause tastes and odors from slime growths.

2. Increased hardness causes excessive use of soap.

3. Increased mineralization causes tastes.

4. Increased corrosivity leads to a water that looks unsightly.

5. Addition of such toxic substances as chromium, arsenic, fluorides, selenium, heavy metals and organic poisons may cause sickness or physiological disturbances.

6. Tastes and odors may result from the organic pollution itself, or from products formed in treating it.

7. Certain minerals, such as iron, manganese and aluminum, may make

the water unsightly, stain porcelain and stain laundry.

8. Underground pollution may increase the ground water temperature, causing it to dissolve more solids and be less serviceable for domestic and industrial purposes.

Slightly injured waters may be satisfactorily treated, but if there are excessive quantities of brine, fluorides or total solids, treatment is not considered economical.

Industrial Water Supplies

1. Scale-forming and prime-creating constituents which increase boiler feed costs may become excessive for low-pressure boilers.
2. Corrosivity may become excessive for small industries.
3. The carbonate-sulfate ratio may become troublesome.
4. Cooling tower operation costs may be increased.
5. Increased temperatures may affect output.

The principal industrial uses of water are steam production, cooling, ice manufacture and processing. A good reference of standards for limits for these various purposes is found in the "Progress Report of the Committee on Quality Tolerances of Water for Industrial Use" (2). Most ground water supplies can be treated and altered by industry to meet these standards, particularly in larger plants, where adequate personnel can be justified, but in smaller plants the more complicated treatments would be impracticable. The cost of treatment should be considered in protecting ground waters. Conceivably there may be examples of gross mineral pollution which would restrict ground water to very limited industrial use.

Irrigational Supplies

1. Increase in the sodium ratio may cause crop loss, depending upon the soil drainage and the type of crop.
2. An increase in sodium alkalinity "tightens" the soil, causing black alkali conditions. This makes the soil almost impervious to water.
3. An increase in boron content may affect citrus and tropical fruit production.
4. An increase in total solids may restrict agriculture to a narrow range of crops.
5. Saltiness in the supply may curtail production.

If any of these objectionable features become critical, it is usually necessary to abandon agricultural activities, as it is not practical to treat irrigational waters. Sometimes better drainage, soil correction and increased fertilization may delay final abandonment.

Examples of Damage

That the injuries to ground waters used for domestic, industrial and irrigational purposes are not just imaginary is evidenced by a number of court cases and other proceedings which, for the most part, are not publicized. A few of these have come to the attention of the author:

1. Impairment of ground water through the disposal of citrus fruit wastes from three industrial plants, affecting one municipal supply and private wells in two rural areas.
2. Impairment of ground water from lye wastes affecting wells in a rural area.
3. Disposal of brine wastes from zeolite softening plants causing wells to be abandoned.

4. Destruction of a 25-mgd. supply from the disposal of oil field brines supposedly into deep wells.

5. Creation of tastes from dichlorophenol discharged from an industrial plant into city sewage and thence into a stream supplying water to the underground.

6. Three instances in different states of salt water penetrating into fresh water strata from oil wells improperly sealed when abandoned.

7. Industrial wastes imparting a varnish-like taste to well water.

8. Gross pollution of upper strata by phenol wastes, forcing six communities to deepen their wells.

9. Discharge of acid wastes underground, causing corrosion of private well casings.

Necessity for Control

In a number of areas, such problems have become sufficiently critical to require control measures. It is apparent that many factors must be taken into account. After the natural characteristics of ground water quality variations have become known, it is essential to determine all the man-made factors causing the variations. All factors causing deterioration must be taken into account, and not all blame can be placed on the disposal of sewage and industrial wastes. It is also necessary to determine all the legitimate public uses and to recommend a program of control for those uses which are economicallly justified and are sound from a conservation standpoint. One should be very hesitant in attempting to fix standards or precise limits to the pollution of ground water by any one industry.

It should be recognized that, if there is no dilution of ground water in those basins being overdrawn or in which water is being mined for domestic purposes, then industry should not contaminate the ground water with wastes in excess of the drinking water standards of the U.S. Public Health Service.

Viewpoint of Industry

It is noted that some states require industries to submit detailed plans and specifications of treatment plants, the general outlines of which have been dictated by state board of health engineers. Some states require industries to reveal their manufacturing processes, in order to learn the sources of different types of wastes. A few states require the issue of permits at the state level. These policies are opposed by industry in general and are fundamentally wrong. They should be abolished. If an industry builds a plant exactly as required by the state department of public health and the plant proves completely inadequate, the industry may refuse to take further corrective action, arguing that it has done just what the state required and will do nothing more. The state has no funds to correct such mistakes as it may be responsible for.

On the other hand, a large number of states have taken an entirely different attitude. They set up objectives for industry to attain. They fix the effluent standards which should be met and leave industry to meet those standards. Full responsibility for plant design and operation rests with industry. Likewise industry has the right to determine what it wishes to run into its plant sewer line and to what extent recoveries of by-products should be made.

Failures by industry to comply with commission requirements may be met, after due investigation, by orders based

on specific requirements for the plant effluent in terms of plant production. Such policies, if administered fairly, appear to be acceptable to industry in those states carrying on successful programs of stream pollution control. But industry has certain rights, and these should be considered:

1. The right to the continued use of surface and ground waters, without impairment of the quality which has been enjoyed in the past.

2. The right to be furnished water by private or public utilities without radical quality changes which would affect production.

3. The right to use streams and ground waters for the reasonable disposition of sewage and industrial wastes.

4. The right to reasonable public sewerage facilities based on the volume of sewage and liquid industrial wastes and the taxes or services the industry renders the community.

5. The right to be informed of the general objectives of a control agency engaged in pollution control.

6. The right to segregate its wastes, recover by-products and design its own treatment works without interference or dictation by any outside control agency.

7. The right to have any orders issued against it written in understandable terms correlated with plant production.

8. The right to have financial assistance made available if benefits would accrue to the public welfare.

TABLE 1

Suggested Specifications for the Classification of Ground Waters

Determinations	Class AA	Class A	Class B	Class C
	Excellent (1, 2, 3)*	Good (1, 2, 3)	Limited (2, 3); and poor (1) even if treated	Unsatisfactory (1, 2, 3)
Coliform organisms per 100 ml., MPN.	<100 (1)*	<1,000 (1)	<10,000 (1, 2)	>10,000 (1, 2)
Sodium ratio	<35 (1, 2)	35–50 (2)	50–80 (1, 2, 3)	>80 (2, 3)
	ppm.	*ppm.*	*ppm.*	*ppm.*
Color	<10 (1)	<20 (1)		
Turbidity	<5 (1)	<10 (1)		
Toxic minerals	<0.05 (1)	<0.05 (1)	<0.05 (1, 2)	1.0 (2)
Heavy metals	<5.0 (1)	<5.0 (1)	<10.0 (1, 2)	10.0 (2)
Iron	<0.1 (1)	<0.25 (3)		
Phenolic compounds	none (1)	<5.0 (1)	<25	>25
Magnesium	<15 (1)	<125 (1)	>125 (1, 3)	
Fluorides	0.5–1.0 (1)	0.5–1.0 (1)	>1.0 (1)	
Total solids	<300 (2)	<500 (1)	500–1,500 (1, 2)	>3,000 (2, 3)
Chlorides	<100 (2)	<250 (1)	500–800 (2)	>800 (2, 3)
Sulfates	<100 (2)	<250 (1)	500–800 (2)	>800 (2, 3)
Sodium bicarbonate	0 (1)	0–50 (2)	50–100 (2)	>100 (2, 3)
Boron	<0.5 (2)	0.5–1.0 (2)	1.0–5.0 (2)	>5.0 (2)

* Limited by (1) domestic, (2) irrigational or (3) industrial requirements.

Standards for Protection

The primary concern is the suitability of ground water for domestic,

irrigational and industrial purposes and its freedom from impairment by increased mineralization, whether by natural change, return of irrigational water, importation of water, exportation of water, overdraft or the possible influence of industrial wastes. Water quality varies in different sections of any one ground water basin, and, in large watersheds, these changes may be radical.

In classifying ground waters, it does not appear feasible to rate them according to the degree of mineral content or by any series of mineral constituents. The irrigational requirements are sometimes more, sometimes less strict, than those for domestic waters. It appears more logical to classify waters according to their suitability for specific uses. The "U.S. Public Health Service Drinking Water Standards" (3) is the best criterion by which to judge the suitability of water for domestic purposes, after reasonable allowance is made for the usual types of treatment. There are no standards for irrigational waters, and there is a wide divergence of authoritative opinion on the sodium ratio and content of sodium alkalinity, boron, chlorides and sulfates for different crops in different soils under a wide variety of practices of irrigation, soil correction and fertilization. The limits set in Table 1 cover wide ranges and are highly tentative, but they may serve as a starting point for much discussion.

Table 1 indicates possible specifications for the classification of ground waters for different degrees of use. These standards are for the classification of ground waters only, and are not to be used as standards of industrial plant effluents which cannot be determined except after exhaustive research into each individual installation.

Acknowledgment

In preparing this paper the author corresponded with more than 50 administrators in stream pollution control and reviewed the organization of 31 stream pollution control agencies. Acknowledgment is tendered to all who so generously co-operated, and it is regretted that a full evaluation of the excellent work being performed in this field cannot be included in this paper.

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Legislation for Revenue Bond Financing

By Stephen B. Robinson

A paper presented on July 23, 1947, at the Annual Conference, San Francisco, by Stephen B. Robinson, Attorney at Law; formerly Special Counsel, Dept. of Water and Power, Los Angeles. An expanded version of this paper will also be presented to and published by the National Institute of Municipal Law Officers and the American Public Power Assn.

A CHARTER amendment recently adopted by the voters of Los Angeles and approved by the state legislature authorizes the city's Dept. of Water and Power to issue revenue bonds for water and power supply. This legislation had been drafted by the department itself with extreme care. It is the result of years of intensive study and consideration, and of detailed discussion with leading municipal bond houses and with bond counsel of national reputation. Possibly it is true that it has been prepared with greater care than any other revenue bond legislation in the country. In a very real sense it reflects the entire experience of the department in the issuance of revenue bonds, for an attempt was made to draft this legislation in the light of this experience and in such form as to meet, as well as possible, all the situations with which the department has been confronted in its somewhat extensive career of revenue bond financing.

The amount of financing done for the water and power systems of the department, both through general obligation and revenue bonds, is shown in Table 1. This volume of revenue bond financing certainly approaches the volume done by any other public body.

The fact that revenue bonds have been issued for so many different purposes, and by so many public bodies, is abundant proof that many laws authorizing the issuance of revenue bonds are on the statute books. On the other hand, it is undoubtedly true that many municipalities or other public bodies at the present time cannot issue revenue bonds at all, or cannot do so on the most advantageous terms, either for the lack of any legislation authorizing such issuance or because of the inadequacy of existing legislation. If the many advantages of revenue bond financing are to be enjoyed by those bodies, their first concern must be to obtain adequate legislation in the form of charter amendments, special acts of the legislature or general laws.

It should be made very clear that the Los Angeles charter provisions are not being presented as a model for revenue bond legislation. It would be foolish to suggest that other municipalities might copy them outright. The constitutional and statutory laws of the various states, the decisions of their courts and the internal organization of their municipalities vary so greatly that any revenue bond legislation must be drawn to fit local conditions. Nevertheless, the author believes that a discussion of some provisions

of the Los Angeles charter, and more particularly of the reasons for drafting these provisions in the form adopted, may be useful to others by suggesting the problems which are likely to arise and the ways in which they can be solved.

No attempt will be made to touch upon all of the numerous provisions of the Los Angeles charter amendment, but some of those which seem to be most interesting and about which questions are most likely to arise will be selected.

Determining Factors

The choice is not always easy. Many factors must be taken into consideration. Constitutional debt limitations, discussed somewhat more in detail later in this paper, and the interpretation placed on those limitations by courts of the state, may have a controlling bearing. If under the decisions of a particular state the issuance of revenue bonds is the incurring of an indebtedness within the meaning of constitutional limitations on indebtedness, and if, for example, those limitations apply to cities, and not to districts, it may be desirable to organize a special water, power or sewer district. If, as in California, the limitations apply to a city but, speaking somewhat loosely, not to its constituent departments, it may be desirable that the authority should be vested in a department, board or commissioner rather than in the general legislative authority of the city, and, if necessary, that such a body or office be created.

TABLE 1

Los Angeles Bonds Issued for Water and Power Supply

General Obligation Bonds		
Water System—new money—1895–1936	$100,425,100 *	
Power System—new money—1910–1939	50,500,000	
TOTAL GENERAL OBLIGATION BONDS		$150,925,100
Revenue Bonds †		
Water System—new money—1935–1938	$ 10,650,000	
Water System—refunding—1940–1943	8,700,000	
Power System—new money—1934–1940	97,749,000	
Power System—refunding—1935–1946	179,565,000	
TOTAL REVENUE BONDS		$296,664,000
TOTAL FINANCING		$447,589,100

* Does not include approximately $5,968,000 refunding bonds (Santa Clara damages) or $975,000 refunding issue of 1935, issued to redeem 1930 bonds held in 1907 sinking fund.

† Includes non-negotiable revenue notes to R.F.C. Does not include $1,000,000 short-term loans made to water system by bank Jan. 15, 1934, repaid Feb. 9, 1934.

Authorization of Bonds

One of the first problems to be met in the drafting of revenue bond legislation is to determine who is to have the final voice in the decision to issue revenue bonds. Authority to issue such bonds may rest with a special board or commissioner having charge of the particular utility, with the general legislative authority of the municipality, with the voters, or, of course, it may rest in part with two or more of these.

If the state constitution guarantees the right of referendum in local affairs, the voters must at least have the opportunity to invoke the referendum, or under certain conditions it may be deemed wise always to refer the question of the issuance of the bonds to the voters.

In considering the effect of constitutional or statutory rights of referendum on the terms of revenue bond legislation, it is important to bear in mind that the weight of authority seems to be to the effect that the authorization of the issuance of bonds, whether they be revenue bonds or otherwise, is a legislative act, and, therefore, in jurisdictions (for example, the state of California) where the right of referendum with reference to *all legislative acts* is reserved to the people of the state and of its several political sub-divisions, it should be assumed, in the absence of express court decisions to the contrary, that the action of a council, board, commissioner—or any other authority but that of the voters themselves—in authorizing the issuance of revenue bonds is subject to referendum, and the legislation should be so drafted as to provide for such referendum, or to be consistent with other laws relating to the exercise of that right.

Local conditions and political likelihood of approval by the authority which is to enact the legislation being drafted—whether that authority is the state legislature, the voters of the city or the legislative authority of that city—must be taken into consideration.

The form of the legislation being drafted will also be affected by the kind of legislation it is. If it is a charter amendment or other special legislation applicable to one community or area, local conditions will, of course, be controlling. In one community the general legislative authority may enjoy and merit the confidence of the public more than a board or commissioner in charge of a particular utility. In another, the reverse may be true. If it is a general law of state-wide application, it must fit conditions generally throughout the state.

Approaching the subject from another angle, there may be more reason to leave the determination of the bond issue to the voters if a new enterprise is being undertaken than if the issue is for the normal extension of an established utility.

The author agrees of course that the voters should determine whether or not a municipality or district should enter a public ownership program for any utility system, or whether it should make some drastic change in that system—as, for example, constructing major works to develop a completely new source of supply. Nevertheless, when the voters have once spoken, and the municipality or district is committed to municipal operation of that utility and has assumed the duty of furnishing service to its inhabitants, the board or commissioner in charge of the works should have the authority to issue revenue bonds in such amounts as are necessary to finance the cost of necessary construction, without having to go to the voters for authority to do so. Of course, such an arrangement would have to be consistent with such rights of referendum as may exist.

L.A. Charter Provisions: Authorization

The provisions of the Los Angeles charter amendment placing the authority for the issuance of water and power revenue bonds are frankly a compromise which took into consideration three factors: what was deemed abstractly most desirable; what was re-

quired under the constitutional referendum requirements; and the known attitude of citizen groups. The charter amendment had been the subject of public discussion long before it was put into final form, and although there was considerable divergence of opinion about where the power to authorize the bonds should rest, it was known that there was a strong faction of citizens of excellent standing who felt that the final decision, except for refunding bonds and possibly some emergency financing, should rest with the voters.

As finally incorporated, the provisions place the power to issue revenue bonds for water and power purposes in the hands of the Board of Water and Power Commissioners, usually subject to what is, in effect, a right of veto by the Council and the Mayor, but with a provision for the overriding of the Mayor's veto by the Council in the same manner as upon the adoption of municipal ordinances. The decisions, however, are always subject to the exercise of the right of referendum by the normal procedure of the filing of a petition by the required number of voters. The right is also reserved to the Board of Water and Power Commissioners to require the submission to the voters of any proposition to issue revenue bonds which has been vetoed by the Council, or by the Mayor and not overridden by the Council.

This general plan is subject to exceptions which eliminate the power of veto by the Council or Mayor over refunding bonds and of certain very limited short-term borrowings, but the right of referendum is always preserved.

Limitations on Amount

There are four kinds of limitations on the amount of revenue bonds permitted to be issued. These are:

1. Constitutional limitations, as interpreted by the courts of the state involved
2. Limitations by general laws, as so interpreted
3. Limitations to be incorporated in legislation authorizing the issuance of revenue bonds
4. Limitations to be authorized by legislation but incorporated in covenants.

Discussion of the fourth class of limitations will be deferred to a later portion of this paper, where covenants in general will be considered.

Constitutional Debt Limitations

Constitutional debt limitations are of vital importance, and sometimes may preclude revenue bond financing unless the constitutional provisions can be changed or the courts can be prevailed upon to change their interpretations.

In most states in which the question has been adjudicated, revenue bonds are held not to be an "indebtedness" within the meaning of provisions which exist in nearly all state constitutions limiting the amount of "indebtedness" which may be incurred by municipalities and other public bodies. The theory underlying this interpretation is that such constitutional limitations have been enacted for the purpose of limiting taxation, and that revenue bonds, not being payable out of tax money, are not an "indebtedness" within the meaning of such constitutional limitations. This has become known as the *broad special fund theory,* and in the author's belief, is sound and logical.

The courts of a few states, however (apparently including California, although the California decisions are not too clear-cut), have placed a sharp limitation upon the application of this

doctrine and have held that any particular issue of revenue bonds does not escape these constitutional limitations unless the bonds are to be paid solely from the revenues of the particular improvement which is to be constructed out of the proceeds of that issue, and not out of the revenues of an entire system to which that improvement will be an addition. This theory has become known as the *limited special fund theory.*

In those few states which adhere to the limited special fund theory, revenue bonds cannot be issued for the construction of an addition to existing water works or other utility property if they are to be payable from the revenues of the entire system. With the utmost deference to the courts which have adhered to this doctrine, the author firmly believes that it is not sound, and that it should be repudiated by them and not followed by other courts.

The limited special fund theory completely loses sight of the fundamental reason for the exclusion of revenue bonds from constitutional debt limitations: that such provisions are limitations upon the power to tax. Applying revenues received from an entire system, partly pre-existing and partly constructed out of the proceeds of the new revenue bond issue, to the payment of such new bonds does not involve any element of taxation.

Further—and again with the utmost deference to these courts—the author believes that it can be shown that the "limited special fund theory" has been evolved on the basis of certain decisions which have later been repudiated by the court that rendered them, and on other decisions which, on careful analysis, can be shown not to have involved the elements on which the courts citing those decisions have believed they were based—in other words, on irrelevant decisions.

One of the most useful steps which the managers of and attorneys for water works, sewer systems or other utilities can take to enable municipal utilities as a class to place their revenue bond financing on a sound and satisfactory basis is to watch carefully for court cases in any part of the country, threatened or actual, in which the right of a municipality or other public body to issue revenue bonds is challenged on the "limited special fund theory," and to call the attention of organizations concerned with municipal utility affairs to such cases, to the end that a concerted effort may be made to eradicate from the "case law" of the country this "limited special fund theory."

Unfortunately it not infrequently happens that some case involving a principle of law of vital interest throughout a state, or for that matter, throughout the nation (for the decisions in one state may become a precedent for similar decisions elsewhere), may arise in some small community, represented by attorneys who may be well-meaning but whose grasp of the principles involved is inadequate, or possibly on occasion by attorneys whose subserviency to powerful but hostile interests may result in such indifference as to amount to connivance in the obtaining of an adverse decision. If organized groups learn promptly of such cases, they may often be able to bring about an adequate representation of the public interest by intervention or *amici curiae* appearances.

Limitations by General Law

Debt limitations by general laws present a somewhat less difficult prob-

lem in the drafting of revenue bond legislation. If the proposed legislation is by general law, its terms can control the existing general law. The same may be true if the new legislation is by charter amendment of a "home-rule" city in states where such charters control the general law. If it is by charter amendment in states where charters are subject to general laws, the remedy is to obtain the amendment of the existing laws.

Limitations in Terms of Authorization

As a matter of policy, it is sometimes felt that certain limitations should be placed on the power to issue revenue bonds in drafting new revenue bond legislation. Of course it is not essential that any such limitations be imposed, but many people feel that unlimited power to issue revenue bonds should not be vested in the municipal authorities, lest they run wild and overload the utility with indebtedness. In the author's opinion there is not much danger of this happening, for there is a more or less automatic check in the fact that no syndicate of bond houses will buy revenue bonds—nor if they did could they sell them to investors—which seriously overload a utility.

It may be wise in drafting legislation, however, to place some limitations on the amount of bonds which may be issued, to guard against any possibility that the utility may be overloaded with debt, and also to increase the probability that the enacting authority, whether it be the voters or the legislature, will adopt the proposed legislation.

L.A. Charter Provisions: Limitations

Lest the Los Angeles charter provisions respecting limitations be a pitfall to others, it should be pointed out that the Dept. of Water and Power escapes the California constitutional debt provisions primarily on an unusual theory, possibly applicable in no other state: that the department is an entity distinct from the city within the meaning of the somewhat peculiar language of the state constitution. It is thus saved from the complexities of the distinction between the "broad special fund theory" and the "limited special fund theory," notwithstanding the fact that the Supreme Court of the state has at least leaned strongly toward the latter theory. Many other utilities must face the complexities referred to and not be lulled into a false sense of security by the fact that the Los Angeles department has avoided them.

Benefiting from this freedom, the Los Angeles charter provisions do not contain any language restricting the funds for payment of a bond issue to the revenues from the works to be constructed out of the proceeds of that issue. These provisions do place a definite limitation, however, on the amount of bonds which can be issued —a limitation which, although it may seem complex at first, is in reality very simple.

The limitation provides that, unless the proposition shall have been consented to by a majority of the voters, the department shall not authorize the issuance of bonds in an amount which, when added to the total amount of bonds issued by the city or the department, and then outstanding, for the particular works involved (water or power), shall exceed the amount of the earned surplus derived from the operation of those works.

The nature and purpose of this limitation may be shown by a homely illus-

tration. Any one who may desire to purchase a home is well within the bounds of conservative business practice if he has one-half of the cost in hand and borrows the other half, securing the loan by a mortgage, trust deed or otherwise. Such a purchaser would have a 50 per cent "equity" in the property. The Los Angeles limitation means that bonds cannot be issued if they would reduce the city's earned equity in the water or power system, whichever is involved, below 50 per cent, unless the voters consent to borrowing in excess of that amount. Ratios of net earnings to principal or interest payments, or both, may be a more familiar basis for debt limitations, but after much deliberation the earned surplus basis was adopted as being simpler and more satisfactory in many ways.

The charter excludes refunding bonds from this limitation, for, of course, they do not increase the outstanding indebtedness.

Term of Bonds

Municipal bonds, whether general obligation or revenue, are usually issued as serial bonds, sometimes with the first maturity deferred for a few years. Unless controlled by constitutional or statutory provisions, it may be desirable to provide for some departure from the "equal annual installment of principal" basis which is common in the issuance of general obligation bonds.

This change permits having a fairly uniform annual obligation for principal and interest payments—usually referred to as a "level debt service"—instead of the initially high but gradually decreasing obligation which results from uniform principal payments and decreasing interest payments. It also permits some adjustment of debt service charges on new issues to compensate for irregularities in total debt service charges on earlier issues, which may result from the overlapping terms of different prior issues or the retirement of some bonds by call.

Although serial bonds are more common, there may be circumstances under which it is desirable to issue term bonds, with sinking fund provisions. The reasons for this are complex and cannot be stated without unduly lengthening this discussion.

The proper answer to the question: Over how long a term of years should the bonds be payable? must, of course, depend upon the particular facts involved. Generally speaking, bonds should not extend over a period longer than the life of the works or property to be constructed or acquired out of their proceeds, and the estimate of its useful life should be conservative.

What this period may be will vary greatly. Bonds for the purchase of fire engines, street cars, busses and other similar equipment of relatively short life should possibly be payable over a period of, say, 15 or 20 years. Bonds for the acquisition of sites and the construction of permanent buildings may properly run for as much as 40 years. Bonds of longer life than 40 years are unusual.

An exception to the general rule is that if bonds are to be issued for additions and betterments which are to be so blended with a pre-existing system that they become in a sense indistinguishable from the rest of the system, and if adequate provision is made for depreciation, and replacements are constantly made, the entire system may be regarded as having an indefinite life, or being in a sense permanent, regardless of the fact that individual

units of property may have a relatively short useful life. Under such conditions, long-term bonds are proper. The water and power systems of the Dept. of Water and Power of Los Angeles offer a good illustration of this procedure.

L.A. Charter Provisions: Term

The Los Angeles charter amendment provided that, unless otherwise consented to by the voters, bonds (other than refunding bonds) should be serial or sinking fund, or a combination of the two; that the retirement of the bonds should be arranged by annual payments on principal (defined to include payments into a sinking fund as well as direct payments), beginning not more than 8 years and ending not more than 40 years after the date of the bonds; that the amounts of such payments should be such that no annual payment due 8 years or more after the date of the bonds should be less than 50 per cent of any subsequent annual payment.

Ignoring minor refinements which would unduly extend the discussion, it was provided that the payments on the principal of refunding bonds be such that at no time would the principal of the new bonds remaining outstanding be greater than the outstanding principal of the bonds to be refunded thereby would have been if they had not been refunded. While accurate statement of the rule requires somewhat complex language, the idea is simple. It merely requires that the refunding bonds be paid off as rapidly as the bonds to be refunded would have been. This provision gives ample leeway to fit the payment schedule to irregularities in debt service obligations which may have resulted from prior redemptions.

Provisions for Redemption

In drafting legislation authorizing the issuance of revenue bonds, provision can be made for issuing bonds which are subject to redemption prior to maturity, and such a provision is highly desirable. The advantage of making bonds subject to call may be well illustrated by the experience of the Los Angeles Dept. of Water and Power. The report of the Controller of the department for the fiscal year just closed shows an aggregate saving of over $29,000,000 through calling outstanding bonds for redemption and issuing refunding bonds. It is true that these savings have been effected during a period of rising bond prices with correspondingly lowered interest costs, and that it is not probable that at any time in the future any correspondingly large savings can be effected through refundings. Nevertheless, in the author's judgment no revenue bonds should be issued without provision for their redemption, except those bonds maturing within a very few years after their issuance. Although at present interest rates are so low that there is not a great probability that they will drop much lower, some slight "upswing" of interest rates has already occurred, and it may not be long before they reach the point at which the right to redeem may be of great potential value. When drafting legislation, of course, it is assumed that it will remain in effect for a considerable period.

Furthermore, particularly with revenue bonds, and entirely independently of the element of effecting a saving of interest costs, it may be desirable at some time to redeem bonds in order to be freed from covenants which, through unforeseen circumstances, have become unduly onerous.

L.A. Charter Provisions: Redemption

The charter not only grants the power to make bonds subject to redemption, but explicitly requires that every bond maturing more than 10 years after its date of issuance shall be subject to redemption at a date not more than 10 years from its issuance and thereafter at intervals not to exceed one year.

Methods of Sale

The question whether revenue bonds (or any bonds) should be sold by competitive bidding only, or, on the other hand, by private negotiation, is one over which there is much conflict of opinion. Sale on competitive bids is in line with the usual practice of awarding municipal contracts by competitive bidding. There may be occasions, however, when a statutory requirement of competitive bidding might defeat the purpose for which the law was enacted. Large and well-established municipally owned utilities, and particularly those which have successfully marketed several issues of bonds, need not fear that they will be hurt by a competitive bidding requirement. The same will probably be true if a city is acquiring a well-established water, electric or other utility system that has a good record of adequate earnings. On the other hand, if a municipality is embarking on a new venture without proved earning ability, and particularly if it is branching out into some relatively new field—possibly the establishment of municipal garages, warehouses, markets or the like—it may find great difficulty in obtaining bids on a predetermined basis, which is essential before competitive bids can be invited. Under such conditions, it may be necessary for the city authorities to negotiate the covenants, matters of segregation of funds and the numerous complex details which enter into a revenue bond arrangement with representatives of some bond houses or syndicate, and to dispose of the bonds by private sale.

It is also argued by some, with considerable plausibility, that even a well-established utility can obtain a better price by private negotiation than by competitive bidding. The reasons supporting this argument are interesting, but a statement of them would unduly lengthen this review.

L.A. Charter Provisions: Sale

The charter requires that all bonds be sold on competitive bidding. This was justified by conditions already commented upon, but may not be justified for all utilities.

Covenants

The matter of covenants is important. Covenants to maintain adequate rates and to prevent sale of the utility without adequate provision for the continued servicing of the bonds are usual, but so simple in their nature that they require no particular discussion. Covenants establishing priorities among different bond issues or limiting the incurring of future indebtedness payable out of the same fund are common, but in the author's opinion require the exercise of a high degree of judgment in their formulation.

Covenants against giving any future issue priority over the present issue or over other issues are justified. There is a great temptation when setting up and marketing a first issue of bonds to go further, however, and to attempt to facilitate their sale through covenants giving those bonds priority over any subsequent bonds issued for

the same works, or through stringent limitations on the amount of subsequent bonds which may be issued.

Giving a present bond issue priority over subsequent issues may possibly be justified if a single unit of property, such as a bridge, is to be constructed, although it is conceivable that at some time within the life of the bonds such major reconstruction may be required as to call for a further bond issue. If bonds are issued to establish, or add to, a water, sewer, electric or other expanding or growing system, it seems to the author to be folly for the issuing entity to give the original bonds priority over subsequent bonds, or to place such drastic limitations on the future issuance of bonds as to run the risk of hampering the financing of future extensions, additions or betterments. One or two bond issues have come to his attention recently in which there is grave reason to fear that major cities have hampered their future operations by consenting to unduly stringent covenants on these subjects.

If a municipal utility is authorized to make contributions to the general funds of a city, purchasers of its bonds may insist on covenants restricting the amount of such contributions. These are closely akin to covenants restricting the incurring of additional indebtedness, and care should be exercised to see that they are not made so stringent as to conflict with the established local policy on such contributions.

Unfortunately in some communities there may be a real danger that interests hostile to public ownership of a utility may gain temporary control of the board in charge of that utility. Where this danger exists it may be wise in drafting legislation to place definite limits on the restrictions which the board may impose on the incurring of future indebtedness or the making of future transfers to general funds, for unduly harsh restrictions can wreck a utility.

L.A. Charter Provisions: Covenants

The charter authorizes priority covenants, but in such terms that the covenant, if made, must be to the effect that no future bonds shall be issued having any priority over bonds theretofore or thereafter issued; covenants to maintain adequate rates; covenants against the sale of the works without provision for the future servicing of the bonds; covenants for limitations on the incurring of additional indebtedness; and covenants for limitations on transfers of funds out of the utility to the general funds of the city.

Miscellaneous Provisions

Many subjects not touched upon in this discussion must be considered in drafting revenue bond legislation. Among the more important may be mentioned matters of negotiability; place of payment; registration; the issuance of duplicates for lost, destroyed or mutilated bonds; the appointment of fiscal agents; the issuance of interim receipts or temporary bonds; reserve funds and trust accounts; waivers by bondholder meetings; conclusive findings of prerequisite facts; and estoppel clauses.

Provisions on all these subjects may be found in the Los Angeles amendment.

Conclusion

The Los Angeles Dept. of Water and Power has found that the marketing of water revenue bonds is somewhat easier than the marketing of power revenue bonds. The financing of water works has had a longer his-

tory than the financing of power works, although of course it was not until comparatively recent years that revenue bonds were issued. Investors seem ready to accept and purchase water bonds with less inquiry and insistence upon detailed information than is usual with power bonds. Consequently, it has been found possible to market water revenue bonds with much less detailed showings of the properties, operations and finances of the water system than has been necessary in the sale of power revenue bonds. For example, on "new money" (as distinguished from refunding) power revenue bonds, it has been found advantageous to furnish for the use of the successful syndicate in marketing the bonds a report of an independent engineer on the properties, operations and finances of the electric system. No such report has seemed necessary for water bonds.

Sewer revenue bonds seem not to have become as well established and seasoned as even power revenue bonds, and it is probably true that the offering of sewer revenue bonds must be accompanied by the presentation of information respecting the properties, operations and finances of the utility in even greater detail than for power revenue bonds.

The author believes that publicly owned utilities, whether they be water, power or sewer systems, or any of numerous other classes of works, will find in revenue bond financing many advantages which do not inhere in general obligation financing. This is particularly true if the legislation authorizing revenue bond financing is carefully drawn. It can have greater flexibility and be better adapted to the needs of a utility system than is usually true of general obligation financing. Furthermore, it tends to place publicly owned utilities on their own responsibility and to answer the charge sometimes made against some classes of utilities that they are leaning upon tax credit.

Putting the financing of a publicly owned utility on a revenue bond basis, instead of on a general obligation bond basis, seems also to have a somewhat intangible but nevertheless real value which is not generally recognized. Revenue bonds impose upon a utility the necessity for standing on its own feet, and this can only be done by good management. You cannot sell revenue bonds unless the utility can show to a practical certainty that it will be in receipt of sufficient revenues to service the bonds as well as pay operation and maintenance costs. The author understands that there are publicly owned utilities and facilities which for years were free to call for tax moneys, in addition to their revenues, with the result that the controlling authorities became politically minded and indifferent to incompetence and carelessness in operation. It did not matter whether the utility paid its way, for there was always the tax treasury to dip into. When these utilities and facilities were put on a revenue bond basis, however, those in control showed a surprising ability to bring about a competent and efficient management and to pile up surpluses instead of deficits. If a utility is on a revenue bond basis, the management must make good or the utility will fold up and those in charge lose their jobs. This is a wholesome compulsion, which will be welcomed by sincere officials. Plainly, revenue bond financing is good for a utility.

Recent Revenue Bond Legislation

By Leonard N. Thompson

A paper presented on July 21, 1947, at the Annual Conference, by Leonard N. Thompson, Gen. Mgr., Water Dept., St. Paul, Minn.; Chairman, Committee on Joint Administration and Collection of Water and Sewer Accounts.

ECONOMIC provision of adequate water and sewerage service to smaller communities, and particularly to suburban communities surrounding metropolitan areas, has long been a difficult problem for municipal officials to solve, and unfortunately its importance has not been realized by the citizens who demand this economical service without paying much attention to the means for providing it.

Generally, the necessity for proper enabling legislation has not been realized, and, as a result, there is over the country as a whole a hodge-podge of statutory provisions. Some of these laws are adequate for some purposes in some states, but few, if any, provide a complete system or code for the procedure necessary to permit any municipality, or group of municipalities, to organize freely and finance to the best advantage.

Adequacy of State Legislation

The Association's Committee on Joint Administration and Collection of Water and Sewer Accounts has made an earnest effort to obtain detailed information on conditions in the individual states represented by its members. A large amount of detailed information on most of the states has been supplied, and will be condensed into a report in which the committee hopes to present as simply as possible an over-all view of the legislative situation as it affects the organization and administration of water and sewer districts and water and sewer departments of incorporated municipalities. At the beginning it is evident that lack of understanding and misunderstanding of the purposes of legislation enabling public corporations to provide needed water works and sewerage utilities have resulted in the failure of most state legislatures to do a thorough job.

From the information so far collected, the author believes that the general observation can safely be made that those states which appear to have enabling legislation which can be considered workable are not satisfied with it, and desire improvement to permit full advantage to be taken of modern methods of organization and finance. On the other hand, those states that obviously have inadequate legislation appear satisfied to let the matter alone. This apathy, particularly on the part of municipal officials—and, it might be added, water works men themselves—is undoubtedly the reason it is so difficult to obtain enactment of the required legislation. On the whole, the necessary tools have not been provided to shape a complete solution to the problem of financing adequate improvements.

Dilemma of the Cities

One of the earliest methods used to finance a utility service was to raise all necessary funds by taxation on property, that is, by the issuance of general obligation bonds supported by property taxes. The ability of a municipality to issue general obligation bonds is of course dependent upon its borrowing capacity, and such bonds can only be issued within the limits set by statutory regulation. Many restrictions are constitutional and cannot be modified by legislative action alone. The necessity of financing the construction or acquisition of new services has posed a grave problem for those city officials who have been caught between skeptical taxpayers on the one hand and a demand for public improvements on the other.

The financing of public improvements by the issuance of revenue bonds, secured only by the revenue and property of an income-producing activity, although a comparatively new method, offers the answer to the perplexing problem and often proves the incentive to better management.

Courts now quite generally hold that a revenue bond does not constitute a debt within the meaning of constitutional and statutory limitations, and the use of general obligation bonds for other purposes is thus not curtailed. Despite certain opposing gestures, at present these bonds are exempt from federal taxation.

The entire tax problem has been complicated by the fact that our municipalities have gradually changed from mere instruments of local governments to huge service organizations. While the demands for more and more services have grown, the base level of local revenue systems has declined steadily since 1930. According to the U.S. Census Bureau, assessed property valuations in the United States dropped 14 per cent between 1930 and 1940, although the necessity for increased revenues regardless of limitations has given rise to increased assessed valuations for tax purposes in recent years. Between 1941 and 1946, assessments in approximately 250 cities increased more than 10 per cent. It has also been observed that, although for a time the bonded debt of cities of over 25,000 population was being reduced, the trend has now been reversed, and bonded indebtedness is rapidly increasing. The natural drift to suburban areas has also caused the value of city properties to decline. It is significant to note that in the same 1930–1940 period, 34 central cities of 140 metropolitan areas declined in population as their surrounding areas increased.

Hedged about by statutory and constitutional limitations, a city is generally severely handicapped in its attempt to operate successfully as a business. Many states now permit the formation by a municipality of corporations or district authorities, separate and distinct from the municipality itself, for the construction and operation of water and sewer systems, financed by bonds payable from revenues.

Many of the public services undertaken by a city today operate in areas far outside their corporate limits. Utility interests of communities are common and often overlapping. According to the latest count, there are 155.067 units of local government in the United States.* If they were spread out

* *The Book of the States, 1945–46*, Vol. 6, p. 61, published by the Council of State Governments, Chicago (1945), lists them as comprising:

Counties	3.050
Townships (or towns)	18.919
Municipalities	16.220
School districts	108.579
Special districts	8,299

evenly, there would be one for each 850 persons. As the spread is not even, however, but seriously overlaps functionally, the Committee on State-Local Relations of the Council of State Governments recently urged intergovernment agreements or, in other words, the creation of districts for utility services.

There is a growing trend to create district authorities, but it is evident that municipal officials, even if they are given the power to manage and to service the debt through revenue bonds, are not thoroughly informed on the need or the possibilities of such authorities. The legislation to create such authorities is not generally satisfactory.

A member of the A.W.W.A. committee, a water works executive of one of our largest cities, expressed himself forcibly and well on this subject of present legislation: "No complete and workable solution of the problem has yet found its way into the statutes of any state. It is a national problem of such import and fraught with such inherent difficulties and prejudices that it requires and deserves the best talent that the country can provide." This statement is supported by facts from a large number of states. It would be impossible to present a critical review of the statutes in every state, but a consideration of some of the difficulties in a few states will illustrate the point.

State Limitations

In the state of California, for example, where cities generally enjoy what is commonly termed "home rule charters," there has been, as far as the author can learn, no extended use of revenue financing. It is possible that under the existing statutes in the state of California, revenue bonds could be issued by the cities. Yet the author is informed that there has been no adjudication in the courts that gives assurance of the validity of such revenue bonds if issued, although it is true they have been eminently successful in certain specific communities, such as Los Angeles.

In Kentucky, the law requires that the petition for creation of a district be signed by 90 per cent of the landowners in the contemplated district. Obviously such a requirement for any petition makes it extremely difficult, and in effect nullifies the legislation. It is much more practical and much more sensible to make a reasonable requirement for signatures on the petition. It is expected that this legislation will be amended in 1948.

In Idaho, recent legislation requires only 10 per cent of the taxpayers' signatures for the petition. In some states there is a 25 per cent requirement; others require a majority—that is, more than 50 per cent.

In Connecticut, one of our thickly populated industrial states, there is a water and sewer revenue bond statute on the books; but again there has been no clear adjudication, and, as a matter of fact, the statute is suffering from disuse. It is possible to issue revenue bonds and to form metropolitan districts, but, with one possible exception, no advantage has been taken of the existing legislation. Many of the public water supplies in that state are privately owned, and that fact may account for the lack of interest in such enabling legislation as the state has.

In the state of New York a serious difficulty arises in metropolitan financing because of constitutional limitations upon the debt-incurring power of municipalities. A simple three-letter word, "any," which was inserted in the con-

stitution at a fairly recent constitutional convention, makes the restriction read to the effect that no municipality shall incur "any debt" beyond the limitations imposed. This casts doubt on revenue financing, which, although not considered a debt within constitutional limitations in many states, might conceivably be considered a debt within the meaning of the constitutional limitation in New York when the word "any" is used rather than the article "a." It is therefore necessary to resort to specific acts of the legislature for creation of each authority having the power to finance itself by revenue bonds.

Much early legislation for revenue bonds was of an emergency nature, and some of the provisions are either inapplicable to present conditions, or occasionally are such as to make the law inoperative.

For example, in Iowa, the revenue bond law limited the sale of bonds to instrumentalities of the federal government. This provision, of course, limits the sale to such agencies as the RFC, and precludes the offers of private bond houses, which would otherwise have been of considerable assistance to the municipality in arranging for the issue, timing its appearance on the market, and so on. Such limitations on the sale of bonds often handicap the municipality in planning a public works program, and in obtaining co-operation from outside financial and bond counsel.

In other states, full use cannot be made of modern means of financing that would be beneficial to towns and cities because of faulty legislation or lack of legislation. Severe restrictions on financing exist in Oklahoma, for example; and in states in the South, such as North Carolina, there is no provision at all for revenue financing.

Florida Decision

Most water and sewage works administrators are familiar with an important decision last year of the Supreme Court of Florida affecting the city of Miami (27 Southern 2nd 118). Three important questions were presented to the court:

1. Are sewer service charges a tax?
2. What is an equitable basis for charge?
3. How can the collection of charges be enforced?

To the first question the court laid down the rule that water and sewer systems were complementary and a sewer service charge was not an exercise of the taxing power but a charge for service, just as the water rate was a charge for *delivering* water.

The second question was settled by the court's ruling that a sewer service charge based on the water supplied was an equitable basis for establishing rates.

The third question was answered by reasoning that the two systems (water and sewerage) were so interlocked that there could be no violation of the owner's constitutional rights by cutting off water to enforce payment of sewer service charges, any more than there would be a violation if water was cut off to enforce payment of the water bill.

Florida is seeking to improve and extend the general law to have these principles apply to *all* cities and districts, without the need for special legislation. Many other states, in which special acts of legislature are necessary, have not indicated their desire for general legislation applicable to all municipalities and districts. Perhaps more individual effort is needed within these states.

It is hoped that these brief illustrations, although rather sketchy, illustrate the need for some concerted action on the part of those who are informed about the situation. The solution will not be found in any reports, but will have to be worked out in the light of information developed by those reports; and it is with that in view that the Committee on Joint Administration of Water and Sewer Accounts has undertaken this broad study of the financial and legislative problems. With continued support and renewed effort in their own individual communities to gain acceptance for improved methods of financing, water works men can ultimately improve the national situation so that each state will benefit to some extent from the work of others.

Cautions and Safeguards

Although the creation of a self-liquidating project is a convenient method of financing certain operations, if soundly conceived and efficiently managed; it must be remembered that revenue bonds can be a source of serious embarrassment if issued under unfavorable conditions, such as too thin a margin of profit, or if issued for undertakings which do not, in the ordinary course of operation, produce revenue at all. Such misuse of these newer methods can easily bring into disrepute all revenue bond legislation.

The Hayes Foundation of Los Angeles has stated:

> Revenue bonds, if employed with discretion and with intelligent regard to their limitations, can become a permanent, important factor in public borrowing and a useful adjunct to the efficient expansion of public services. They can readily, on the one hand, not only be discredited but can be made to reflect discredit on the issuing public agencies. . . they throw the spotlight of publicity on the capacity to function with business-like efficiency. . . . To realize the potentialities fully, however, it will be necessary for legislatures to take constructive action in improving the statutes authorizing the use of revenue bonds and for the users to apply them intelligently for legitimate purposes.

Eminent bond counsel have expressed their views on the subject upon several occasions, a brief summary of which would include the following principles:

1. Good revenue bond legislation should not limit the authority of the issuing body too narrowly. It is impossible to foresee all the problems which will arise in the construction, acquisition or expansion of different properties. The bond market and the profit and loss statement will generally provide adequate restraints upon those charged with the management and the duty of financing.

2. If bonds are issued for constructing a new project, the problems are different from those of an issue for the purchase of an existing private property or the extension of a going property. They are generally more speculative and therefore are rarely sold on as favorable terms. Provision for refunding issues should therefore be made at a time when it is a going, profitable business.

3. Bonds should be open-end issues to allow further borrowing capacity if required, with, of course, protection provided for holders of current issues. Ordinarily it is provided that such bonds may be issued when the revenues available for debt service are 12 per cent of the debt charges for the original, plus proposed, issue.

4. Because the investor in revenue bonds can look only to the utility for security, the utility must be on a sound

business basis if the bonds are to be sold advantageously.

5. Rates should be sufficient to meet all operating costs, debt retirement, repairs, maintenance, depreciation, and leave at least a 10 per cent safety margin.

6. The utility should maintain adequate insurance, with provision for application of the coverage to the repair of damaged property.

7. Complete records and accounts of operations should be kept, and it is important to engage competent and experienced consulting engineers and good legal advice.

Conclusion

The author can safely conclude that:

1. Revenue bonds have been growing in popularity but have not been used too extensively, either because of lack of enabling legislation, timidity or lack of understanding.

2. There is a trend towards district commissions or authorities.

3. Some form of revenue bond legislation exists in about 35 of the states, in about 22 of which the authority has been used to a degree ranging from moderate to extensive.

New legislation on revenue bonds, generally in the form of amendments, was recently introduced in the states of Massachusetts, Montana, Nevada, Utah, Vermont and Wisconsin. At the time this information was obtained, final action on the bills had not been taken.

The report of the committee will be prepared for publication so that the membership of the entire Association may have an opportunity to review the information and offer constructive suggestions to clarify the confusion.

The author feels certain that it will be the consensus of the committee that study, followed by a definite campaign of public education, should be conducted by responsible and informed public officials in each individual state. No one is better able to do this than officials of water works and sewerage departments, with such help as they can get from private and governmental organizations.

One of the difficulties the committee has faced is the apathy or complacency of officials and the public generally toward the need for better financial procedure. If nothing else is accomplished by its efforts than the establishment of the fact that serious study of existing methods of raising revenue is necessary, it is believed that something will have been contributed of future benefit to many towns and cities.

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Quaternary Ammonium Germicidal Treatment for Jute-Packed Water Mains

By Alfred L. Sotier and Harry W. Ward

A contribution to the Journal by Alfred L. Sotier, Bacteriologist, Research Dept., Wyandotte Chemicals Corp., and Harry W. Ward, Supt. of Water Purif., Dept. of Municipal Service, Wyandotte, Mich.

IF untreated commercial jute or hemp packing is used in a water main, water from that main is likely to show a positive test for coliforms for several months. A number of investigators have studied this problem and most are agreed that the packing material is at fault.

Gettrust (1) has recommended steam pressure sterilization of all packings before use. Arnold (2) has implicated jute as the source of contamination, and recommends steam pressure sterilization. LaDue (3) has stated that chlorination is not trustworthy for correcting this condition, and believes that mercuric chloride is the most effective chemical to use. Calvert (4) has advanced the idea that jute, hemp and even cotton packing materials contain nutrients which will support coliform organisms, and that before these materials are used they should be subjected to a chemical treatment which will remove or inactivate these nutrients. He advocates the use of "Klerol," an organic mercury compound for this purpose. Adams and Kingsbury (5) have concluded that jute will support bacterial life within a water main even though sterile when placed in the pipe. Spaulding (6) has shown jute to be a source of contamination in new mains, and has concluded that chlorination is an unsatisfactory method of sterilization.

It is evident that the sterilization of both jute and jute-packed water mains is a difficult problem. Hemp offers the same problem. Chlorine treatment is still used widely (7), but is not always a solution to the problem. Repeated applications at levels as high as 200 ppm. are usually necessary, and months may elapse before an infected main is sterilized.

Recently the Wyandotte Chemicals Corp., Wyandotte, Mich., was faced with the problem of sterilizing two jute-packed water mains which had failed to respond to repeated treatments with sodium hypochlorite. There was urgent need to put these mains into service quickly, and, because further treatment with hypochlorite threatened to run into considerable delay, it was decided to try a quaternary ammonium germicide. As far as is known this was the first time quaternary ammonium compounds were ever used for this purpose, although Fair (8) has reported on the use of these materials for the destruction of cysts of *Entamoeba histolytica* in potable waters.

Formulation of Germicidal Mixture

The quaternary ammonium compound used in this work was 2-2-4-4 tetra-methyl-butyl-phenoxy-ethoxy-ethyl-dimethyl-benzyl-ammonium chloride monohydrate.* Previous work not related to water supply has shown that this particular quaternary ammonium compound is very effective as a germicide when used with a modified soda approximating in composition a Na_2CO_3-$NaHCO_3$ ratio of 1 : 1.39.

Such a mixture, consisting of 5 per cent of the quaternary ammonium compound and 95 per cent of the modified soda, was prepared as an experimental product by the Wyandotte Chemicals Corp., and called "Polymine D." The alkali portion of the formulation is not to be looked upon as an inert carrier, since it serves as a detergent and activating agent for the quaternary ammonium germicide.

The concentrations of quaternary ammonium germicides usually are not given or calculated in percentages or parts per million, but in dilutions of the active agent. Thus, if a material contains 5 per cent of the quaternary ammonium salt, and is used as a 10 per cent solution, the active agent dilution of the solution will be 1 : 200. If used as a 5 per cent solution, the active agent dilution becomes 1 : 400, and so on. This method of expressing concentrations is very useful in work with disinfectants, and is generally used when working with quaternary ammonium germicides.

The surface tension of use-solutions of this formulation ranges from 35 to 45 dynes per centimeter, and solutions will form suds upon shaking. Use-solutions are noncorrosive to iron and the common metals, and noncaustic to the skin. They are odorless, but not entirely tasteless.

Treatment of Mains

One of the mains was a 4-in. line 300 ft. long; the other was a 6-in. line 3,000 ft. long. The shorter main was used for experimental treatments. For the first attempt at sterilizing the shorter main, the pure quaternary salt was used at an active agent dilution of 1 : 500. The main was blown out with air and the solution introduced by siphoning from 55-gal. steel drums. Some difficulty was experienced from foaming. Approximately 135 gal. of solution were required to initiate a flow at the far end of the main, and an additional 30 gal. were fed in to flush out the diluted first few gallons of solution. The main was then capped at both ends and allowed to stand full for 21 hours. It was emptied by removing the caps and flushing with city water for 40 minutes. Bacteriological tests showed that the treatment had not been successful.

Meanwhile, laboratory work was started on samples of the jute that had been used for packing the mains. Three identical 1.0-g. samples were placed in sterile flasks. One flask received 500 ml. of a 1 : 500 dilution of the pure quaternary salt. The second flask received 500 ml. of a 4 per cent solution of Polymine D (corresponding to 1 : 500 dilution, quaternary salt basis). The third flask received 500 ml. of a sodium hypochlorite solution at a strength of 300 ppm. of available chlorine.

It was immediately evident that the Polymine D solution was removing more dirt and debris than was the simple quaternary ammonium solution, although even this removed more

* Made by Rohm and Haas, Philadelphia, and known as Hyamine 1622.

than did the hypochlorite solution. The flasks were shaken for several short periods and allowed to stand overnight.

Figure 1 shows the germicidal solutions after the jute had been removed from the flasks and the liquid had been poured into clean beakers. The liquid in beaker No. 1 is very opaque, due to the dirt and debris which the Polymine D solution removed. The liquid in beaker No. 2 shows less dirt and debris removed by the simple quaternary solution, and in beaker No. 3 the liquid is relatively clear.

Bacteriological testing of the treated jute indicated that both the simple quaternary ammonium solution and the Polymine D solution had sterilized the jute, but the hypochlorite solution had failed despite a residual of 78 ppm. of available chlorine at the time of removing the jute from the solution.

This work suggested that the next attempt at sterilizing the main should be made with a solution prepared with the quaternary compound and mild alkali. Accordingly a second treatment was given, using Polymine D at a quaternary salt dilution of 1 : 500. This time the solution was fed into the empty line with a small electrically driven portable pump, a procedure which resulted in less foaming. After filling the main, only the far end was capped, and a pressure of 35 to 40 psi. was maintained on the line. The pressure was released and reapplied several times a day in order to get a breathing action which, it was hoped, would aid in penetrating and thoroughly wetting the fibers of the jute.

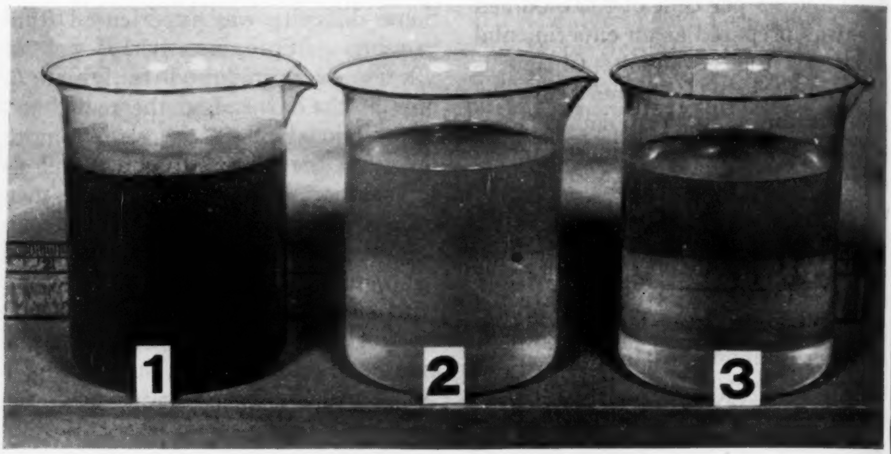

FIG. 1. Appearance of Germicidal Solutions After Treating Jute
1—Polymine D, 2—Simple quaternary ammonium compound, 3—Sodium hypochlorite

The contact period was 2 days. At the end of this time, the main was drained and flushed for 40 minutes before taking a sample for bacteriological testing. The results of this treatment were very encouraging: the count was 6 organisms per ml., and the 24-hour lactose broth tube results indicated a low coliform index, although by the end of 48 hours all broth tubes were positive. It was felt that a longer contact period might result in success.

The third attempt at sterilizing the short main was identical with the second except that the contact period was one week. Accumulated air and foam were allowed to escape from both ends of the main once a day for the first three days, and more solution added to keep the main full. At the end of the week of contact, the main was drained and flushed, and a 1-in. stream of water allowed to discharge for two days before sampling was started. This first sample showed the absence of coliform organisms, as did a second sample taken four days after the treatment. These results were independently confirmed on additional samples taken over several days by the Wyandotte Water Dept. The main had been sterilized.

The knowledge gained in treating the shorter main offered a hope that the 3,000-ft. main could be sterilized with one treatment. For this undertaking approximately 4,000 gal. of solution were required. An elevated platform was built for the support of the mixing drums, and the solution was allowed to flow into the main by gravity. The portable electric pump was employed to give a pressure of 35 to 40 psi., and again foam and air were bled out of the main daily for the first three days and the loss made up with fresh solution. No difficulties developed, and the filled main was allowed to stand for one week. Both mains were treated during July and August.

TABLE 1

Treatment of 6-in. Lengths (Approximately) of Hemp

Chemical	Concentration or Dilution	Dry Weight of Hemp	Wet Weight of Hemp	Gain	Remarks
		g.	*g.*	*g.*	
Klerol	3 mg. Hg/gram	8.8	23.4	14.6	Hemp darkened
Polymine D	1–100 quaternary salt basis	8.4	35.6	27.2	Hemp darkened
Polymine D	1–130 quaternary salt basis	8.7	27.3	18.6	Hemp darkened
Polymine D	1–260 quaternary salt basis	8.3	26.3	18.0	Hemp darkened
Tetrosan	1–37.5 quaternary salt basis	7.8	24.6	16.8	Hemp light in color
Noxtane	Satd. soln.	7.7	29.1	21.4	Hemp darkened
Chloramine B	800 ppm. av. Cl	8.7	28.9	20.2	Hemp slightly bleached
HTH-15	850 ppm.	8.4	16.4	8.0	Hemp bleached but spotty
Clorox	836 ppm.	9.2	28.6	19.4	Hemp strongly bleached
Water (control)		8.9	23.8	14.9	

After this treatment the main was drained, thoroughly flushed, and a sampling program started. All samples over a 4-day period were negative for coliform organisms. The Water Dept. was advised of the results and again confirmed the findings independently.

Three-Day Cycle Test

Following the successful treatment of the two mains a test known as the "Three-Day Cycle Test" was brought to the authors' attention by C. K. Calvert of the Indianapolis Water Co.,

with the suggestion that packing material be subjected to this test, using not only the quaternary ammonium compound, but other agents as well.

The Three-Day Cycle Test consists of soaking the packing material for 18 to 24 hours in the solution under test; draining, drying, and finally shredding the sample; and placing it in a sterile jar. An ordinary 1-qt. Mason fruit jar is satisfactory. Next, 900 ml. of tap water are added, and the jar is shaken and put aside to incubate at 20°C. for 3 days. At the end of this 3-day incubation period, the jar is shaken and allowed to settle for 30 minutes, after which 1-ml. volumes are plated with nutrient agar. After making the plates, the water is drained from the packing material, using the lid to hold back the fibers, and a fresh volume of 900 ml. of tap water is added. The jar is again shaken and returned to the incubator for a second cycle. These 3-day cycles are continued for two months or longer. A successfully treated sample will give counts that are low at the start, or moderately high dropping quickly to low and continuing low thereafter. An unsuccessfully treated sample will give high counts at the start, and these will continue to be high for months.

The test can be looked upon as a measure of the ability of the treated packing material to supply nutrients to the organisms normally found in tap water, which is rarely sterile.

Experimental Findings

The experiment included 7 compounds of which three were chlorine-liberating type germicides.

These were:

1. *Klerol*—an organic mercury compound containing 2.128 per cent mercury. Made by the Reilly Tar and Chemical Co.
2. *Polymine D*—a Wyandotte Chemicals Corp. experimental product containing 5.0 per cent of a quaternary ammonium germicide (Hyamine 1622) activated by a modified soda
3. *Tetrosan*—a 10.0 per cent quaternary ammonium solution made by Onyx Oil and Chemical Co.
4. *Noxtane*—a Wyandotte Chemicals Corp. product used to control fungal stains on green lumber, containing 17.5 to 20.0 per cent of sodium pentachlorophenate
5. *Monochloramine-B*—an organic chlorine compound liberating 25.0 to 28.0 per cent available chlorine
6. *HTH 15*—a hypochlorite type product containing 15.0 per cent of available chlorine, made by the Mathieson Alkali Works, Inc.
7. *Clorox*—a household bleach containing about 4.8 per cent available chlorine.

All of the chlorine-liberating agents were used at an available chlorine level approximating 800 ppm. "Klerol" was used at Calvert's recommended figure of 3.0 mg. of mercury per gram of hemp. "Polymine D" was used at three levels giving quaternary salt dilutions of 1 : 100, 1 : 130 and 1 : 260. "Tetrosan" was used at an active agent dilution of 1 : 37.5. It was planned to use "Noxtane" at a concentration of 40 mg. of sodium pentachlorophenate per gram of hemp, but at this concentration much of the "Noxtane" failed to dissolve even with heating. The hot saturated solution was decanted for use.

The packing material used in the experiment was a braided hemp rope of square cross-section measuring ½ in. on each side. A 6-in. length was used

TABLE 2

*3-Day Cycle Test on Hemp**

Date Set	Date Plated	Klerol 3 mg. Hg/gram	Polymine D 1:100	Polymine D, 1:130 Quaternary Salt Basis	Polymine D, 1:260 Quaternary Salt Basis	Tetrosan, 1:37.5 Quaternary Salt Basis	Noxtane Saturated Solution	Chloramine B, 800 ppm. Available Cl	HTH-15, 850 ppm. Available Cl	Clorox, 836 ppm. Available Cl	Water Control
		Count per ml. of water									
2/12/46	2/15/46	0	0	128	224	0	0	TNC	—	—	TNC
2/15/46	2/18/46	0	0	224	384	0	0	TNC	—	—	TNC
2/18/46	2/21/46	0	0	101	TNC	0	TNC	TNC	TNC	—	TNC
2/21/46	2/25/46	0	0	70	352	0	10	TNC	TNC	—	TNC
2/25/46	2/28/46	0	0	38	112	1	9	144	TNC	TNC	TNC
2/28/46	3/4/46	0	0	70	104	2	TNC	TNC	TNC	TNC	TNC
3/4/46	3/8/46	0	0	58	TNC	0	TNC	TNC	TNC	TNC	TNC
3/8/46	3/11/46	0	0	49	134	2	12	TNC	TNC	TNC	TNC
3/11/46	3/14/46	0	0	72	176	1	TNC	TNC	TNC	TNC	TNC
3/14/46	3/21/46	0	0	40	32	2	TNC				TNC
3/21/46	3/25/46	0	0	42	64	0	TNC	Discarded	Discarded	Discarded	TNC
3/25/46	3/28/46	0	0	32	56	1	8				TNC
3/28/46	4/2/46	0	0	46	96	2	8				TNC
4/2/46	4/5/46	0	1	80	96	1	TNC				TNC
4/8/46	4/12/46	0	0	41	51	1	TNC				TNC
4/15/46	4/18/46	0	0	24	80	1	384				TNC
4/22/46	4/25/46	1	2	20	128	2	96				TNC
4/29/46	5/2/46	1	0	12	80	1	8				TNC
5/6/46	5/10/46	4	2	40	96	1	TNC				TNC
5/13/46	5/16/46	0	3	20	TNC	1	TNC				TNC
5/20/46	5/28/46	0	2	50	512	3	TNC				TNC
AVERAGE		0.3	0.5	60	—	1.0	TNC	TNC	TNC	TNC	TNC

* TNC—too numerous to count.

for each test. The data for weights and treatment are given in Table 1.

Residual chlorine determinations were made on the chlorine-liberating solutions following the soaking period. These all showed high residuals, 480 ppm. for Monochloramine B, 124 ppm. for HTH-15, and 487 ppm. for Clorox. Thus the HTH-15 solution showed the greatest loss of chlorine. The Clorox showed the greatest bleaching action.

Plate counts of the water from the jars were made in duplicate, using Bacto nutrient agar. Incubation was for 24 hours at 37°C., after which counting was done by one observer using a Quebec Counter. The plate count data for the 7 compounds tested are given in Table 2.

The 3-day cycle test on hemp packing indicated that "Klerol," when used at a level of 3 mg. of mercury per gram

of hemp; "Polymine D," when used at an active agent dilution of 1 : 100; and "Tetrosan," when used at an active dilution of 1 : 37.5; gave successful treatments. Polymine D, when used at a quaternary salt dilution of 1 :130, gave counts under 100 after the third cycle (an average count of 60); and such results are regarded as successful. At a quaternary salt dilution of 1 : 260, Polymine D did not give a successful treatment.

Noxtane gave erratic but generally poor control. Since it was used as a saturated solution, it is evident that it has no value for the treatment of water main packings. (As expected, none of the three chlorine-liberating germicides gave a successful treatment.)

Discussion of Results

The sterilization of new water mains in general need not be a serious problem. The use of only thoroughly presterilized packings, and the exercise of care to keep all soil, clay and other contaminants out of the pipe as it is being laid reduces the hazard of a contaminated main greatly. Swabbing each section of the pipe with a germicide as it is installed, covering the open end during lunch periods and overnight, and in every other way preventing the access of contaminating material to the pipe is essential to bacteriologic cleanliness. On such jobs, a final treatment is carried out by filling the pipe with a germicidal solution containing 50 ppm. available chlorine. After a few hours the pipe is emptied and flushed and will then usually be found acceptable for use. Unfortunately some installations fall short of these ideals, and accidents occur. Once a main is finished and covered, it becomes very expensive to dig it up. If it is found to be contaminated, an attempt is usually made to treat the main in a manner that will obviate uncovering and dismantling it. Under such circumstances chlorine is usually tried, but often with little success, if the pipe is seriously contaminated. It is believed that alkali-activated quaternary ammonium compounds can be used to great advantage under these conditions.

The cost of treatment is always an important consideration. Quaternary ammonium compounds are not cheap and probably will never compete with chlorine for general water sterilization. For such specialized purposes as are developed in this paper, however, in which use the chlorine compounds are not well adapted, the expense may be justified.

The effectiveness of quaternary ammonium compounds is reduced by strong mineral acids, certain polyphosphates and proteins, soap and anionic wetting agents, but none of these are ordinarily found in water systems.

Because so few mains have been treated, there has been no opportunity to investigate fully the concentration-holding time relationship required for optimum efficiency, nor has the effect of temperature been studied. The work here reported was done during the months of July and August, when the temperature of the treating solution was a few degrees higher than it would be during the winter months. It should be pointed out that quaternary ammonium germicides are quite effective at low temperatures. On the other hand, summer temperatures favor the proliferation of bacteria in water mains.

Conclusions

Two jute-packed water mains have been successfully sterilized by a mild alkali-activated quaternary ammonium

germicide formulation (Polymine D) used at a quaternary salt dilution of 1:500 with a contact period of 7 days.

Laboratory studies have shown the detergent action of a mild alkali-activated quaternary mixture to be high. The success of solutions of such a mixture can be attributed to high germicidal power plus surface-active and detergent properties which enable them to wet out fibers of jute or other packing material quickly and effectively, and to remove dirt, nutrients and debris if these are present. These unusual requirements for a satisfactory solution of this problem are, obviously, almost never encountered in routine germicidal practices.

Hemp packing material was successfully sterilized in the laboratory with a single overnight treatment in a mild alkali-activated quaternary ammonium solution containing the germicide at a quaternary salt dilution of 1:100 as judged by the 3-day cycle test. At a dilution of 1:130 the treatment was less successful but still practical. At half this concentration (1:260), the treatment was unsuccessful.

"Klerol," an organic mercury compound, gave a successful treatment in the laboratory when used at a concentration giving 3 mg. of mercury per gram of hemp.

The chlorine-liberating compounds tested failed to give a successful treatment of hemp in the laboratory when used at available chlorine levels as high as 800 ppm.

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Abstracts of Water Works Literature

Key: In the reference to the publication in which the abstracted article appears, **39**:473 (May '47) indicates volume 39, page 473, issue dated May 1947. If the publication is paged by the issue, **39**:5:1 (May '47) indicates volume 39, number 5, page 1, issue dated May 1947. Abbreviations following an abstract indicate that it was taken, by permission, from one of the following periodicals: *B.H.—Bulletin of Hygiene* (*British*); *C.A.—Chemical Abstracts; Corr.—Corrosion; I.M.—Institute of Metals* (*British*); *P.H.E.A.—Public Health Engineering Abstracts; W.P.R.—Water Pollution Research* (*British*).

STERILIZATION

Break-Point Chlorination for Manganese Removal at Montebello Filters. S. E. Edwards & G. B. McCall. Proc. 19th Ann. Conf. Md.-Del. W. & Sew. Assn., p. 16 (May '46). When Mn seasonally (July–Oct.) excessive in Baltimore raw water, lime and $FeSO_4$ substituted for alum, increasing pH of coagulated water to 9.0. Observations in '44 indicated Mn removed by filters during pre-chlorination to true residual in effluent. During critical period in Oct. (max. 1.75 ppm. Mn), coinciding with turnover in impounding reservoir, chlorinator capac. insufficient for free residual chlorination, 0.35 of 0.45 ppm. effluent residual being chloramine. Effluent Mn increased to 0.15 ppm., and lime and $FeSO_4$ again resorted to, activated C being required to remove algal tastes. In '45, 3 rotameters enabled application of 26.6 lb. Cl per mil.gal. (avg.) during critical period, effluent contg. 0.4 ppm. true residual Cl and no Mn, 25% Mn being removed in settling basins and 75% in filters. Part of latter due to catalysis. Glass-tube filter contg. 18" Mn-coated sand from filters and operated at 2 gpm. per sq. ft. completely removed 0.5 ppm. Mn from untreated raw water for 24–36 hr., effluent thereafter contg. Mn. Treatment of sand with strong Cl soln. restored eff. for Mn removal. Despite raw water of poorer bact. qual., effluent of better qual., no confirmed coliform organism tests (10 and 1 ml.) being recorded during yr. No consumer complaints have resulted from residuals as high as 0.6 ppm., although formerly 0.25 ppm. considered limit. Complaints decreased from 516 in '40, when avg. residual 0.17 ppm., to none in '45, when avg. 0.37. Chem. cost in Sept. and Oct. '45 18¢ per mil.gal. less than in same period in '40 with lime and $FeSO_4$. Cost of coagulation with alum and with lime and $FeSO_4$ essentially same and increased cost for Cl more than offset by saving on activated C, none being required with free residual chlorination.—*R. E. Thompson.*

The Special Qualities of Electrolytic Hypochlorite for Water Treatment. R. F. Milton & J. L. Hoskins. Wtr. & Wtr. Eng. (Br.) **50**:32 (Jan. '47). NaOCl solution prepared by electrolysis of dilute brine solution—using carbon electrodes and low density current—undoubtedly possesses oxidizing characteristics different from both chlorine water and sodium hypochlorite soln. prepared by passing chlorine gas into NaOH. Numerous investigators have attempted to isolate substance in electrolytic solution responsible for enhanced oxidizing action. Suggested that it is due to free hypochlorous acid, but other tests show that this acid is not solely responsible for oxidizing ability of electrolytic solution. That freshly prepared chlorine water does not contain free hypochlorous acid may be illustrated by test with diphenylamine. Action of electrolytic solution is approx. 50% more rapid than that of chlorine water. Use of chlorites in sterilization has been emphasized in N. America, where cheap electrolytic processes have been set up near Niagara Falls. Results of tests (in England) indicate that with same quantity of "available chlorine" electrolytic hypochlorite has more rapid bactericidal effect than chlorine water or commercial hypochlorite. In treatment of swimming pools, electrolytic hypochlorite should have much to recommend it since: high concns. are without unpleasant

effect, rapid bactericidal action is of value where continuous pollution is occurring, and there is no loss by diffusion into surrounding air as with chlorine. Advantages outlined above apply only to *freshly prepared hypochlorite*.—*H. E. Babbitt.*

The Sterilization of Potable Water With Iodine. T. J. Buergers & W. Kalies. Münch. med. Wochschr. (Ger.) **91**:19:245 ('44); Chimie & industrie (Fr.) **52**:66 ('44). Drinking water may be disinfected by adding 1 ml. of tincture comprising 7 parts of iodine, 3 parts of potassium iodide, and 90 parts of alc. to 7 l. of water. Water treated in this way free from pathogenic organisms after 5 min. This procedure suitable for use by troops in field or for disinfecting emergency water supplies. Simple and rapid, and treated water has no taste or odor and does not endanger health.—*W.P.R.*

Iodine Purifies GI Water. Sci. News Letter **50**: 324 (Nov. 23, '46). Quarternary ammonium and tri-iodides investigated under OSRD contracts in effort to find water disinfectant more satisfactory than chlorine compds. for military purposes. Triglycine hydroperiodide showed highest military characteristics. Article indicated that tablets dissolve quickly, liberate 7.5 ppm. elemental iodine, enough to kill cysts of amebic dysentery germs quickly and reduce no. of typhoid, cholera and bacillary dysentery germs from about 100,000,000 to 5 or less per 100 ml. of water. Addnl. tests planned.—*P.H.E.A.*

Influence of Water Vapor on Ozonizer Efficiency. C. E. Thorp & W. J. Armstrong. Ind. Eng. Chem.—Anal. Ed. **18**: 1319 (Dec. '46). Graphs presented to show relation of ozonizer eff. over large range of absolute and relative humidities. Absolute humidity shown to influence ozonizer eff. greatly when above 0.001 g. of water per g. of air (dew point, −17°C.), but to have no influence below this optimum point. Relative humidity has no effect on ozonizer eff. Large installations usually include air drying provisions and curves given enable engr. to predict in advance how much drying will be needed for ozone equip. Procedure in testing detailed. —*Ed.*

Water Quality Improvement With Ozone. Victor Hann. Eng. News-Rec. **139**:59 (Jul. 10, '47). Sterilization and taste, odor and color removal by ozonation described, with particular reference to construction of world's largest ozone generator at Philadelphia, Pa.—*Ed.*

The Ozone Method of Water Purification. E. Howlett. Wtr. & Wtr. Eng. (Br.), **50**: 25 (Jan. '47). Ozone unknown in absolute purity except as explosive liquid, dark, almost black, and opaque when more than 0.1 in. deep. Virtually colorless in gaseous state, mixed with large quantities of oxygen, but has penetrating odor irritating to mucous membranes. Gas in highly ionized state and is endowed with remarkable chem. activity. Complete sterilization of water effected in few minutes. Ozonized water, either fresh or salt, has sparkling appearance and does not produce irritation to eyes, nose and throat experienced by bathers after immersion in chlorinated water. No foreign agent prejudical to health introduced into water. Ozone in air in concn. of 1 ppm. or more retards growth of bacteria and molds. Timber subjected seasoned in few days instead of usual months or years. Use of ozone more highly developed in France. Approx no. of plants for ozonizing water supplies in different countries are: France, 90; Italy, 14; England, 6; Roumania, 3; U.S., 2; Russia, 1. Ozonization removes yellowish tinge of raw water and any offensive smell and disagreeable taste. Can be produced by: chem. action, electrolysis, ultraviolet rays, radioactive elements, incandescent solids, evapn. of sea water, and electrostatic field. For industrial purposes, most favored method has been silent elec. dischg. If turbid, water must be clarified before being ozonized. Process consists of producing ozone by silent dischg. through air and intimate mixture of ozonized air with clarified water. Plant required, assuming elec. supply of 400 v., 3 phase, 50 cycles, comprises: air desiccator with motor-driven fan, ozone producer with high-tension cooling tank, one or more emulsers with self-contact chamber, de-saturator for elimg. excess of ozone, motor-driven alternator with regulator for giving 500 cycles, and transformer for raising voltage to approx. 20,000. In '40 consumption of power in watts per 1000 gal. (Imp.) of water, was: Nice, Avignon, Vittel, 45; Paris, Toulon, 55; Ashton-under-Lyne, Lanc., Eng., 64; Nancy, 68; Brest, 90. Admitted that ozone treatment usually costs more than chlorination. In ozonization, minute organic solid matter in suspension is oxidized, and decomposed constituent elements transformed into gas. Small plants

for continuous sterilization of water made. App. to be put on market will function on any a.c. between 110 and 240 v., 50 cycles. Will provide 10–30 gph. (Imp.) with current consumption of 40 w. Electronic app. now being mfd. which may supersede present rotary type, materially reducing capital and running costs. Possibility of producing ozone by means of low pressure mercury discharge arc, if successful, would reduce costs to min.—*H. E. Babbitt.*

Treatment of Water by Ozone. M. T. B. WHITSON. Surveyor. (Br.) **103**:111 (Mar. 10, '44). To augment information regarding moorland water at Knott Hill ozonization plant, model app. used. Ozonizer composed of aluminum alloy electrodes and mica dielectrics. Elec. current 50 cycles, 220 v. from mains. Air dried by passing through $CaCl_2$ dessicator. With air flow 660 ml. per min. and water 1800 ml., concn. of ozone is 3.4 g. per cu.m. air. By increasing air to 832 ml. per min. with water of 1450 ml., ozone is 5 g. per cu.m. of air. Model gives similar results to prototype only when operated between limits of 1.25 to 1.72 g. per cu.m. of water. Dosages up to 3 g. per cu.m. of water can be given at Knott Hill. Model designed to allow water to remain in contact with ozone for 4 min. Similar to Knott Hill plant. Although tests primarily intended to provide information regarding color removal, bact. and odor removal results also given. At Knott Hill Res. dosage of ozone set at 1.72 g. per cu.m. water treated, model set to give similar dosage. Results show model effects much same color removal as prototype. Color reduction in neighborhood of 50% throughout 7 yr. At Brushes Res. color reduction 59%. Color reduction in Yeoman Hey water, in test carried out in Knott Hill plant in '37, 50%. At Lower Swineshaw Res. with limited quant. of ozone available, i.e., 1.7 g. per cu.m. of water, color reduction not great. At Chew Res. limitations of model confined color removal to 32%. Higher concns. of ozone than were available necessary for highly colored waters. *Discussion. Ibid.* **103**:139 (Mar. 24, '44). S. G. BARRETT: Urged that report of Non-Ferrous Metals Research Assn. be waited for before concluding that chlorine has effect on taps. In tests carried out on Newcastle water with initial color of 100° Hazen, application of 2 gpg. (Imp.) of alum reduced color to about 90° but 2½ gpg. reduced color to 5°. Appears that threshold value exists for alum dosage which must be reached before any improvement effected in color. A. BOOTHMAN: Chlorine gas quick to destroy bact. poln. but no one can foretell effects of residual chlorine taken into human system day after day. Sterilization of water by ozone should, therefore, be encouraged. R. H. CUTHBERTSON: Chlorine simpler method and most readily applicable in all conditions. In Sheffield, during expts. with super-chlorination, color reduction as high as 75% experienced. In sterilization by ozone no residual sterilizing agent carried into distr. system. When small quant. of chlorine maintd. in distr. system its disappearance can be regarded as indication that contamn. gaining access. *Author's reply*: Some difficulty experienced with Hazen app. No two persons could arrive at same result. Decided to expt. with Lovibond improved tintometer. No difficulty in obtaining uniformity of results found. Ease with which chlorine can be applied to water, even in small quants., has insured its success, but where large quants. dealt with at central works question of simplicity not deciding factor. French sum up matter by calling chlorination "un procédé de fortune" and ozonization "le procédé de choix." Ozone does not provide residuum in distr. system. There is, therefore, no effect on metal in mains. Ozonization breaks down if Mn present in concn. exceeding 0.2–0.3 ppm. Ferrous iron can also interfere with process. Process being successfully applied in France to great variety of waters. —*H. E. Babbitt.*

The Cysticidal Effects of Chlorine and Ozone on Cysts of *Endameba histolytica*, Together With a Comparative Study of Several Encystment Media. J. F. KESSEL, D. K. ALLISON, M. KAIME, M. QUIROS & A. GLOECKNER. Am. J. Trop. Med. **24**: 177 ('44). Quantitative expts., made to compare effects of solns. contg. 0.5 and 1.0 ppm. residual chlorine and 0.3 ppm. ozone respectively on cysts of *Endameba histolytica* and on various species of bacteria, including *Esch. coli*, *Alcaligenes faecalis*, and strain of *Streptococcus*, described. pH values of test solns. ranged from 5 to 9. In order to prevent variations in pH value, which might affect cysticidal and bactericidal action, from occurring during expts., solns. buffered. Growth of cysts of *Endameba histolytica* in several different media studied; from this study concluded that most effective medium for production of cysts was buffered liver-infusion agar. Method of prepn. of

this medium, which was used in all subsequent expts., described. Solns. contg. 100 cysts or 500,000–1,000,000 bacteria per ml. used in tests. Temp. of solns. maintd. at 27°C. throughout both series of tests, and number of cysts and of bacteria remaining in solns. after intervals of time ranging from 2 to 120 min. recorded. Results, which are expressed graphically, showed that when gaseous chlorine used to produce 0.5 ppm. residual chlorine and pH value 6 or 7, cysticidal and bactericidal activities of solns. greater than when same concn. of residual chlorine obtained by addn. of calcium hypochlorite (H.T.H.) but with pH values of 5 and 9 application of gaseous chlorine and H.T.H. gave similar results. Activities of chlorine and ozone both greatest in soln. with pH values of 5. Cysticidal and bactericidal activities of ozone and cysticidal activity of 1.0 ppm. chlorine remained same in solns. with pH values between 6 and 9, but bactericidal activity of 1.0 ppm. chlorine and cysticidal and bactericidal activities of 0.5 ppm. chlorine less in solns. with higher pH values. Time taken to kill cysts and bacteria considerably less in solns. contg. 0.3 ppm. ozone than in solns. contg. either 0.5 or 1.0 ppm. residual chlorine. Ozone destroyed cysts in half time required to destroy bacteria, but it is pointed out that concn. of bacteria used much greater than normally encountered in water which requires disinfection.—*W.P.R.*

Emergency Sterilization of Drinking Water With Heteropolar Cationic Antiseptics. II. Persistence of Germicidal Action Within Intestinal Tract and Removal of Excess Drug With Adsorbing Agents. F. J. Moore & Jessie Marmorston, with the technical assistance of F. Golden & N. Anderson. Am. J. Trop. Med. **26**:5:729 (Sept. '46). Heteropolar cationic antiseptics which are effective against g.-negative bacteria and amebic cysts may be removed from soln. in biologically inert state by adsorption on colloidal clays. This adsorption does not significantly reverse accomplished antiseptic action. Reversal of germicidal action does not appear to occur within gastronitestinal tract of mouse.—*B. H.*

FIRE PROTECTION

Deductions From Research on Use of Water. H. Adeler. Natl. Fire Protection Assn. Quarterly. **40**:283 (Apr. '47). In Europe, increasing attention paid to most effective use of water in fire fighting and prevention of excessive water damage. Combustible buildings render outside fire fighting with massed fire streams necessary, yet even under such unfavorable conditions inside fire fighting favored. Latter made increasingly possible by small hose, self-contained breathing app., and buildings with heavy floors and incombustible walls and partitions. These measures and "smoke divers" who can make way to seat of fire despite O_2 deficiency and heat have rendered great peacetime fires rare in Copenhagen. Classical calcns., based on heating value of wood and latent heat of evapn. of water, indicate theoretical water requirement 0.6 gal./lb. Stanzig (Vienna), on basis of radiation of 3000 cal. per min. per sq.m., estd. requirement at about 120 gpm. per 1000 sq.ft. fire area. With 100 sq.m. (1076 sq.ft.) as operational area of jet or stream, "standard" jet should be about 130 gpm. On basis of wood impregnation experience, 120–150 psi. pressure required at impact. On this reasoning, Vienna practice employs 2″ hose lines and high pressure. Expts. in Copenhagen by Friis with small piles of sticks on weight scale, confirmed on larger test piles, indicated: (1) Wood burns in several distinctly separate stages. After short ignition stage, during which wood dried and heated, combustion stage begins. In latter, thin outer layer develops gas which leaves wood as flame or smoke, interior remaining white and intact but becoming smaller as gas layer works inward. Outer charcoal layer does not glow, gas emitted preventing access of air. Only when core gone and gas emission stops does charcoal burn. This is glowing stage—no flames, but charcoal burns brightly and gradually consumed. During combustion stage, temp. not very high, heat being carried away by gases, but in glowing stage intense heat accumulated in wood. Combustion stage lasts about 10 min. in wood of ordinary dimensions. (2) Extinguishment during combustion stage requires less water than hitherto believed—as little as 3% of that indicated by latent heat of evapn. Heat contained in fire, not that developed by fire, important factor, and in combustion stage this quite low. More water required in glowing stage, but less than

indicated by classical calcn. Expts. corroborated Stanzig's calcn., based on initial charcoal temp. 1500°C. and sp.ht. 0.2, namely 0.06 gal./lb. (3) High nozzle pressure not necessary, water being very readily absorbed by charcoal, gas emission apparently not being hindrance. (4) Difference between superior and inferior stream very small. Stream just little smaller than sufficient to extinguish fire ineffective in glowing stage. When fire not too large for jet to control entire area and still largely in combustion stage, min. superior jet indicated by formula: $Q = t/4000$, where Q = gpm./sq.ft. of burning surface and t = min. Thus, approx. 1–2 qt./min./sq.yd. will produce stream superior to ordinary fire. If much heat already present, approx. 1 gpm./sq.yd. as rule superior. Hence, in most cases, jet of approx. 50 gpm. per 1000 sq.ft., and often half this, sufficient. High pressure (130–175 psi.) desirable for good distr. through ricocheting. Energetic movement of nozzle also effective. Vienna practice includes subdivision of buildings into fire compartments not exceeding 5000 sq.ft. and many small fire stations equipped with small light engines and for small streams. Danish fire app. carry small "first aid" hose, and nozzle pressure of 40–80 lb. in general use, depending on vigorous play of nozzle for distr. In Sweden, 90–130 psi. used. Tests there showed 550 lb. burning wood extinguished with little as 5 gal. from small hose. Mohlin's nozzle can be attached to either 1 or 2.5" hose. Often, 2.5" hose supplies three 1" lines. Fog extinguishment also being studied. 16 references.—*R. E. Thompson.*

Spontaneous Combustion and Its Prevention. EDWARD A. DIETERLE. J. Western Soc. Engrs. **49**:2:68 (June '44). *Part I.* During past 15 yr. no. of fires avgd. 660,000 annually in U.S., costing about $380,000,000 each yr. Of these, 37,000 per yr. attributed to rubbish and spontaneous ignition. Spontaneous heating and ignition occur where chem. reaction can occur and liberate heat; if heat not dissipated as rapidly as released, temp. of mass builds up to ignition point. Bact. action in hay, grain, seeds and other agric. products, peat, cellulosic wastes in general and leather produce unstable compds. which subsequently oxidize, first raising temp. to thermal death point of organisms then to ignition temp. For gaseous materials ignition temp. lowered by as much as 200°F. if water vapor or finely divided particles present; this lowered ignition point designated as "nuclear ignition temp." Nuckolls has classified spontaneously ignitable materials as follows: *Group 1*—Incombustible substances which may cause ignition, such as unslaked lime, calcium carbide, etc. *Group 2*—Substances having ignition points below ordinary temps., such as sodium in the presence of water, phosphorus in air, turpentine or ammonia in chlorine. *Group 3*—Combustible substances which may undergo oxidation at ordinary temps. to reach their ignition point, such as vegetable oils, charcoal, coal and finely divided metals. *Group 4*—Org. material subject to microbial thermogenesis, such as various farm and barnyard products. Moisture should be kept from lime and other Group 1 substances. Group 3 responsible for most spontaneously caused fires. Careless handling of oily rags should be avoided. Any oils contg. unsatd. compds. subject to spontaneous heating. In expt. oil-soaked mass of rags rose 20°C. in 1 hr. and in 2½ hr. burned on reaching 360°C. Iodine number of oils often taken as index of spontaneous combustibility. While mineral oils not considered subject to spontaneous combustion, cracked polymers from clay towers highly unsatd., contg. olefins and diolefins, which have caused fires in improperly deposited wiping rags. Blending of mineral with vegetable or animal oils makes mixture subject to spontaneous ignition. In cleaning fractionating towers contg. ferrous sulfide formations access of air should be preceded by thorough purge with steam to avoid explosions. Sweeping compds. and floor oils contg. oxidizable substances should be watched carefully. Fibrous oily wastes should be deposited in tightly covered metal containers and destroyed daily. Charcoal and carbon should be dry when storing. Steam pipes should be placed no closer than 2" to a wooden structure. Liability of material to spontaneous heating tested in Makey calorimetric app. With coal the finer the particle size the greater the chances for spontaneous heating from several reactions: (1) oxidation of pyrite, (2) oxidation of unsatd. sulfur compds., (3) oxidation of org. unsaturates without forming carbon dioxide, and (4) oxidations resulting in carbon dioxide, carbon monoxide and water vapor. Moisture causes coal to pack, reducing cooling effect of ventilation but requiring extra heat to raise temp. to burning point. Pyrites cause swelling and disintegration into smaller fragments. Rate of heat generation related to geol. age; anthracite safest to store, while bituminous coals safe if not broken by dropping from

heights or not piled too high. Heat formed by coal stored during winter less than when stored during summer. Under-water storage safest but usually not practical. Pyramidal or conical piles permit larger pieces to flank outside while fines tend to segregate as central core where slower circulation of air reduces ventilation. Insertion of pipes or old boiler tubes not recommended as air moving within fines may start spontaneous heating. Outdoor location with adjacent vacant space for removal by crane desirable. Wooden fences should not be near. Piling coal over manhole cover, which may allow ingress of air, and near hot water pipes or furnaces dangerous. Best piling method is in flat thin layers for uniform distr., as in a cake, rolling each layer to remove channels. Rapidly melting snow or water vapor rising from pile after rain indicates generation of heat; odors indicative of heating zones. Break-thread thermometers or thermocouples inserted within pile and read weekly show heating in incipiency. Temps. of 120 to 125°F. dangerous; at 180°F. combustion shortly follows. Ignition temp. of coal about 450°F. If ignition likely, usually starts within 3 mo. after piling. Water hydrants should always be installed near coal. "Hot spots" may sometimes be quenched by inserting water pipe to reach troubled portion, thereby avoiding necessity of removing remainder of pile. Water gas from quenching and coal gas formed by distillation noxious. Some storage piles provided with means for carbon dioxide injection. On shipboard tar sprayed over surface of coal makes it less pervious to air.—*A. A. Hirsch.*

Water Supply Standards Improved by Underwriters' Reports. L. D. WALKER. Wtr. & Sew. **83**:5:29 (May '45). Activities of Canadian Underwriters' Assn., supported by upwards of 170 insurance companies, in regard to inspection of municipal fire protection described. Reports of inspections, with recommendations for improvements, regarded as confidential and supplied to member companies and municipal councils. Repitition of recommendations beneficial in improving conditions regarding fire prevention and protection and in reducing insurance rates. Requirements of assn. std. regarding water supply, fire and police depts. and bldg. regulations outlined. Ratio of fire to ordinary water requirements depends on pop., and is 1:1 for pop. about 60,000. Min. main diam. for satisfactory fire service 6", with cross-connections at intervals not less than 600'; otherwise, min. 8". No single fracture should isolate more than 500' of main in high-value districts or 800' elsewhere. Hydrants should be not more than 250' apart in former nor 500' in residential areas.—*R. E. Thompson.*

The 1944 Fire Loss. ANON. N.F.P.A. Quarterly. **38**:3:204 (Jan. '45). Prelim. est. of U.S. fire loss for '42, '43 and '44 released by NBFU. These figures, based on insurance losses, with fixed percentage of allowance for uninsured and unreported losses, do not reflect increased contribution to national fire loss made by fires in uninsured government-owned properties. Such losses not currently reported through any central agency, but it appears clear from fragmentary information available that, if these uninsured government losses were included, fire loss curve would show still more pronounced upward trend.

Aggregate Loss for 29 Yr. Over $11,000,000,000

1916	$258,377,952	1930	$501,980,624
1917	289,535,050	1931	451,643,866
1918	353,878,876	1932	400,859,554
1919	320,540,399	1933	271,453,189
1920	447,886,677	1934	271,197,296
1921	495,406,012	1935	235,263,401
1922	506,541,001	1936	266,659,449
1923	535,372,782	1937	254,959,423
1924	549,062,124	1938	258,477,944
1925	559,418,184	1939	275,102,119
1926	561,980,751	1940	285,878,697
1927	472,933,969	1941	303,895,000
1928	464,607,102	1942	314,295,000
1929	459,445,778	1943	373,000,000
		1944	423,458,000

—*Ed.*

Delayed Water Improvement Results in Big Westboro Fire. HENRY T. HANSON. Fire Engineering **100**:233 (Apr. '47). Entire town of Westboro, Mass., (6500 pop.) threatened by $500,000 fire on Mar. 4, '47 destroying 2 factories. Fire station only 50 yds. from fire. Firemen handicapped by poor water supply. Problem of water supply long a controversial subject; disaster predicted for many years by retired fire chief Blois. Appropriation of $380,000 made last year for high pressure reservoir, large mains, high pressure hydrants. Material delivered but not installed at time of fire. Would have provided static pressure of 148 psi., flow of 4000 gpm. at 70 psi. residual. Available water supply at time of fire cut down by open sprinkler systems. Description of fire-

fighting technique. 7 existing hydrants used during fire but not all at same time because of lack of water.—*A. C. Rener.*

Emergency Water Supply Basins, Dams, etc. E. G. Powell. Wtr. & Wtr. Eng. (Br.) **46**:505 (Dec. '43). Paper prepd. for meeting of Southeastern Dist. of Inst. Munic. and County Engrs. In dealing with question of adequate water supplies for fire fighting necessary to pay attention to factory areas considered high fire risk. Fortunately, simple matter to allocate static water basins in particular factory estates. Water provided in small rectangular tanks of 5000- to 7000-gal. (Imp.) capac. Circular steel tanks vary in size from 7000 to 22,000 gal. (Imp.). Further emergency water storage allocated in form of brick and concrete circular tanks of 10,000 to 22,000 gal. (Imp.) capac. Sumps consist of pre-cast concrete tubes, 3′ in length, sunk in bed of water-courses adjacent to roadways. —*H. E. Babbitt.*

Discharge From Fire Hydrants. H. Cannell. Wtr. & Wtr. Eng. (Br.) **46**:229 (June '43). Fig. shows type of connection fairly widely used, consisting of 3″ connection to main, length of 3″ pipe and duckfoot enabling hydrant to be placed in footpath when main is under road. In making calcns. shown in Table 1, length of 3″ pipe taken at 10′ and loss of head in ft. calcd. by Kutter's formula. Values in fifth column based on actual expts. All calcns. based on clean surfaces. As total head loss depends on many factors, variation in one does not greatly affect final results. If more hydrants than one opened, discharge from each hydrant will be much the same as for single hydrant, until total discharge becomes large enough to reduce seriously working pressure in main. Opening further hydrants will decrease discharge from those already open. Optimum no. of hydrants to use on 8″ main is 3 or 4 and on 9″ main 4 or 5 Hydrant in center of 800-yd. length of main fed at both ends gives discharge equal to hydrant situated only 100 yd. from single trunk main. Not advantageous to use more than 2 hydrants on 6″ main, 2 hydrants on 4″ main and more than 1 on 3″ main. (Hydrants referred to are 2½″ in diam.). Main advantage of fire-engine sump is that more than one engine can use it at a time, while with hydrant only 1 engine can be coupled up and water available may not be fully utilized. In testing hydrants working pressure should be taken on all large mains at time of max. demand. Pressures need be taken on small mains only when complaints of poor pressure received. Results obtained valuable. Show badly incrusted mains and partly closed valves or other obstructions. Best type of hydrant flow gage is Pitot tube. 2″ fan-type meter fitted in 2½″ standpipe gave satisfactory results up to 150 gpm. (Imp.).—*H. E. Babbitt.*

TABLE 1

Flow—*gpm.* (Imp.)	Entrance to 3″ Pipe	Friction in 3″ Pipe	Duckfoot Bend	Screw-down Hydrant	Standpipe		Veloc. Head at Dischg.	Total
					Pipe	Elbow		
100	0.2	1.5	0.2	4	0.2	0.7	1	7.8
200	0.9	6.2	0.8	16	0.9	2.8	4	31.6
300	2.0	13.3	1.8	36	2.0	6.8	9	70.9
400	4.0	25.0	3.0	64	3.0	11.0	15	125.0
500	6.0	39.0	5.0	100	5.0	19.0	24	198.0
1000	22.0	167.0	20.0	400	22.0	69.0	96	796.0

The Shreveport Hydrant. T. L. Amiss. W.W. & Sew. **90**:4:119 (Apr. '43). About 100 hydrants equipped with duplex valve invented by employees of Shreveport, La., Dept. of Water and Sewerage now in service in Shreveport and elsewhere. 2 gates operate on single stem. Lower gate, cushioned with rubber bushing closes with water pressure behind it. Upper or operating gate closes immediately after lower gate. Advantages claimed: no loss of water if hydrant barrel broken; hydrant (including operative valve gasket) overhauled with main in service; relief of pressure on operating valve during closure resulting in easy shut-offs and longer valve life; elimn. of valves in hydrant branches.—*F. J. Maier.*

FOREIGN WATER SUPPLIES—GENERAL

Water Supply Problems of the Arctic. A. B. Cronkwright. Pub. Wks. **78**:8:18 (Aug. '47). Water abundant and of excellent qual. during summer in Arctic. During winter most streams and shallow lakes either dry or frozen solid. Smaller Army installations depend on mechanized equip. for hauling water from deep lakes but this sometimes impossible during severe weather. Snow melting machines too inefficient for continuous operation. Distr. piping laid on ground surface and insulated. The 6″ mains enclosed in 36″ × 18″ box packed with Kimsul. Box also contains steam distr. line. With water at plant 33°F. and outside temp. −41°F. for several days, water delivered never below 86°F. Arctic Army stations should be located near deep lakes for source of water and insulation for distr. piping should be fireproof.—*F. J. Maier.*

Bromine Content of Some Saline Waters in South Australia. W. Ternent Cooke. Trans. Roy. Soc. S. Australia **65**: 2: 212 ('41). Brines contained 350–5600 ppm. Br. Lake water contained 5–270 ppm. and sea water 70–131 ppm. Br.—*C.A.*

Expansion of Water Supply for the City of Graz [Austria]. G. Krevets. Gas, Wasser, Wärme (Austrian) **1**:124 (May '47). The central water system started in 1872 by a private company was taken over by the city 1911. Water requirements during World War I increased 41%, during the next 19 years by 6%, and during World War II by 54%. The water works can supply 100,000 people; present estimate 250,000. Daily water use per capita has increased from 294 l. in 1937 to 502 in 1946, with a daily max. of 628 and hourly max. of 1062 l./capita. Unaccounted-for water has increased from 2% in 1933 to 27% in 1945. On the basis of hydraulic studies, expansion is possible from old and new wells, each with its own pumping station. Studies on ground water replenishment showed that in an average year rainfall is 37.7″, runoff 26.5″ with 11.2″ lost. The question whether ground water from beneath a large city, bordering on a stream into which the untreated sewage of about 100 l./capita is dischgd., required study. The *Esch. coli* content of river varied from 12 to 8250/ml.; test wells 35 to 42′ from the river showed 11 total bacteria as compared with 15,000 in the river, and no coliform organisms. Ammonia was low. To determine effect of gas works on river and ground water, phenol detns. made. Effluent from gas works showed 352 ppm., whereas 1200′ below the river showed only traces. Introducing 100 l. gas waste with 2400 ppm. ammonia and 1800 ppm. phenol into a driven well, three wells 75′ away were found to contain traces of phenol and ammonia after 2–3 days, which had disappeared in 6 days. Of great importance is possibility that, by reducing ground-water level leaky sewers, industrial wastes, septic tanks and a greater degree of infiltration from the polluted river may cause contamn.—*W. Rudolfs.*

Observations on Evident Pollution in Water Supply Plants. H. Bruns. Water. *A Yearbook for Water Chemistry and the Technic of Water Treatment.* **XV**: ('41–'42). Verein Deutscher Chemiker. Verlag Chemie, G.m.b.H. (Ger.) ('42) 368 pp. Discusses cases of gross poln. of water supplies in Germany and Poland. In winter of '06–'07 sudden frost caused water near banks of Ruhr R. to freeze. Amt. of water pumped by 1 pumping station decreased to such extent overnight that high-lying and outlying parts of distr. system short of water. Bed of river and river banks dredged to remove ice and sludge. Water supply in this dist. river water which has been filtered through banks. After river had been dredged, water in neighboring wells turbid for day or two; bact. count very high for 1 wk. and did not return to its normal value for several weeks. *Bact. prodigiosum,* introduced into river above place of dredging, observed in water of wells 50 m. from river bank 3 to 4 hr. later, and could be detected in outlying parts of distr. system for 4 wk. Apart from turbidity and slight increase in amt. of oxygen consumed from potassium permanganate, water supply showed no chem. abnormalities. Author emphasizes importance of knowledge of local conditions in interpreting results of anals. of water. In one part of Poland well waters contain large amts. of chloride and very hard. Inorg. salts in water partly derived from underground deposit. In such dist. insistence on max. permissible limit of 50 mg. of chlorine per l. would condemn nearly all supplies. Water may contain considerable amts. of org. matter in form of humic acids derived from soil and may yet be potable. Rain water mixing with spring water may reduce content of inorg. matter and yet cause

temporary poln., which may have disappeared before samples taken for anal. In estg. qual. of spring water, observations at different seasons and under different climatic conditions, and knowledge of geology of dist. essential. Relation between water supply and occurrence of typhoid in Ruhr dist. discussed. Many towns on Lake Constance and on larger lakes in Switzerland have used untreated lake water for many years. For example, at Friedrichshafen water taken from points not exposed to poln. and at depth of 30 to 40 m. below surface of lake. In recent decades epidemics of typhoid, which have occurred at Paderborn, Lippstadt, Detmold, Jena, Pforzheim, and other places, have been due to poln. of spring water by surface water. Investigation of cause of outbreak of paratyphoid in small community described. Value of fluorescein tests in tracing sources of poln. of water supplies discussed and examples of its use given. Geology and water supplies of western Poland in region of Warthe R. described. Poln. of water in distr. system discussed and acct. given of cases of poln. due to entry of farm drainage into damaged pipes.—*W.P.R.*

Progress in Water Supply. Health Ministry Report for 1945–46. Anon. Surveyor (Br.) **106**:283 (May 30, '47). Water Act came into effect Oct. 1, '45 and while substantial progress in year of transition was not possible there was widespread activity in planning future action. Although main activity was planning, vol. of work approved was considerably in excess of previous year. Surveys were made by Minister's engrs. of number of areas including counties of Cornwall, East Sussex (and others). Consideration has been given to control of ground water abstraction in Luton Area, North-West Home Counties (and others). Formal applications for grant (for rural water supplies) from 47 local authorities totaling £4,000,000. Loans sanctioned amounted to approx. £1,155,000. General rainfall over England and Wales was 33.3" or 6% less than avg. '45 was 5th yr. in succession in which rainfall failed to exceed avg. Flows in rivers Thames and Lee continued well below normal.—*H. E. Babbitt.*

Notable Water Undertakings III.—Shrewsbury. Anon. Wtr. & Wtr. Eng. (Br.) **50**:186 (Apr. '47). Old part of town surrounded by R. Severn and water, of some sort, always available. Citizens in 16th century looked for source of pure water and found it in spring known as Conduit Head at point 2 mi. or so from town. In 1669 Stone conduit in Green Market erected. As early as 17th century reservoir for Severn water was situated "upon the Town Wall near Mr. More's garden on Clarimond Hill." First organized attempt to deliver Severn water into houses in 1827. In 1878 undertaking was purchased by corporation for £40,000. From 1878 to 1906 council constantly had under consideration numerous upland and river water schemes. In '06 Water Committee advised council to concentrate on improving existing works. In Feb. '30 recommended entirely new river scheme. Work commenced in '33 and completed in '35. Works comprise river intake, pumping works, storage reservoir, treatment works, surface pumping station and elevated water tower. Nevertheless old conduit supply has been maintd. to this day. Jan. '47 Council decided not to maint. (conduit) supply indefinitely but to allow it to lapse with deterioration of distr. system.—*H. E. Babbitt.*

Atomic Bombing Effects on Japanese Water Supply Systems. Anon. Pub. Wks. **78**:8:25 (Aug. '47). Well field used as source of water for Hiroshima 1½ mi. north of city. Avg. consumption 17.8 mgd. (50 gpd. per capita) treated by slow sand filters and chlorination. Bombing had little effect on plant except lab. damaged and all records destroyed. Service pipes to bldgs. heavily damaged; estd. 70,000 broken or leaking. Only one major break in distr. system occurred at river bridge crossing. Nagasaki served by 5 systems each consisting of impounding reservoirs and filter plants with post-chlorination. All plants but one undamaged with no water shortage experienced. Numerous breaks occurred in service piping and 9 breaks found in distr. piping; most of these being fractures in c.-i. pipe caused by increased earth pressure resulting from explosion. No epidemics resulted from possible contamn. resulting from backflow caused by breaks and negative pressures. Generally damage to water systems slight. Numerous private wells (15,000 in Hiroshima; 10,000 in Nagasaki) would have supplied sufficient emergency water if municipal system failed. —*F. J. Maier.*

Automatic Control of the Filters and Pumping Station at Witharen. G. J. J. HALLINK. Water (Neth.) **31**:87 (Mar. '47). Works, consisting of raw water pumps, 3 prefilters and 3 secondary filters with spray devices to remove CO_2, gradually changed from manual operation to automatic control. Hand-operated valves replaced by hydraulic valves with internal packing glands and sleeves. All filters periodically washed at same time, when clear well is full, to obtain highest eff. $KMnO_4$ is added automatically for oxidation. Many of parts required, including elec. panel and wiring, constructed at plant.—*W. Rudolfs.*

Water Supply in the Middle East Campaigns [*See also* Jour.A.W.W.A., **39**:499 (May '47)]. **VII. Syria and the Lebanon.** G. L. PAVER. Wtr. & Wtr. Eng. (Br.) **50**:61 (Feb. '47). Hydrologically Syria and the Lebanon consist of: (1) coastal plain, (2) the Lebanon, Anti-Lebanon, Ansariye and Zaviye mountain ranges, (3) Rift Valley, (4) Damascus-Palmyra folded region, (5) Inland Desert, (6) Jebel Druze region, (7) Euphrates Valley, and (8) Eastern Turkish Border. Each is topographically and geologically distinct and water occurrence in each is characteristic. Coastal plain and mountain regions well supplied by perennial streams. No streams exist in inland areas where water obtained from wells and seasonal springs. Salinity of water no great problem in Syria, worst areas being Euphrates Valley where 3000 ppm. and along Iraq border where 17,000 ppm. has been recorded. In broad stretch along Euphrates and extending some way into desert appreciable amts. of magnesium sulfate have been encountered. In sands, gravels and alluvials of coastal plains and in limestones supplies of potable water of 1000 gph. (Imp.) have been obtained from holes 6–10" in diam. Boreholes in mountain areas have yielded 5000 gph. (Imp.). In Bekkaa Valley boreholes near main drainage lines may produce 5000 gph. (Imp.). In marl area surrounding Aleppo supplies of 1000 gph. (Imp.) can be expected. **VIII. Cyprus.** G. L. PAVER. Wtr. & Wtr. Eng. (Br.) **50**:247 (May '47). Drilling for water in Cyprus undertaken on fairly extensive scale for military purposes. Cyprus well-developed island with comparatively dense pop. engaged chiefly in agriculture. All readily available water supplies have long been developed. Geology and hydrological conditions fairly well established. Pptn. much controlled by topography, max. amt. of over 25" per annum falling on Troodos Mt. and Kyrenian Range. Low-lying Mesaoria receives less than 15". No rivers truly perennial. Borings made in coastal plain. Where conditions favorable, supplies of fresh water present above underlying saline water, and potable water can be obtained within 200 yd. of sea. At Nicosia aerodrome development of underground water took place by boring consistently throughout war. Iso-resistivity map typical of technique carried out. Successful application of resistivity method of geophysical prospecting for sites for boreholes for water (shown by record of 46% success before '43 and 84% success thereafter).—*H. E. Babbitt.*

The Water Supplies of Soviet Armenia in the New Five-Year Plan. GEORGI AGAKHANYAN. Wtr. & Wtr. Eng. (Br.) **50**:140 (Mar. '47). If irrig. canals of Soviet Armenia were lined up they would stretch for many thousands of miles, yet territory covers only 18,000 sq.mi. and only score or so of yrs. ago irrig. in Armenia was practically nonexistent. In years of Soviet rule irrigated area has been trebled. Constr. of large storage reservoirs is being started. Work has begun on constr. of Stalin canal to irrigate large area now barren near foothills of Mt. Ararat. Next year will see opening of Garnin canal. Numerous other irrigation projects could be enumerated. —*H. E. Babbitt.*

Water Supply in the Donets Coalfield. I. V. ABRAMOV. Wtr. and Wtr. Eng. (Br.), **49**: 129 (March '46). Work started on restoration of water supply for industrial and domestic needs of Donets coal field and industrial region of Ukraine. Supply of good quality water serious problem. 16 years ago Donets Water Supply Trust cleaned out beds of rivers, cleaned out ponds, joined up reservoirs, built dams and sank artesian wells. Trust had good supply of modern machines and was able to supply 1 bil.cu.m. of water per year. Gigantic canalization project drawn up to join Volga and Don, and Dnieper and Donets, by canals to bring water of these big rivers through Donets valley. Germans ruthlessly destroyed water supply system, took most of valuable equipment to Germany, blew up and flooded mines, forming underground lakes. Work on water supply being carried on parallel to general reconstruction of region. Building of Konstantinovka Res. on Byk R. first measure towards implementing plans made before war. Water system of Donets Basin will be completely rebuilt during coming 5-year period.—*H. E. Babbitt.*

STREAM POLLUTION CONTROL

River Reaeration. AVERILL J. WILEY, LEONARD PARKINSON, HARRY W. GEHM, THEODORE F. WISNIEWSKI & A. F. BARTSCH. Paper Trade J. **124**:12:59 ('47). Method of Tyler, consisting of diffusing compressed air beneath surface of river which has been pold., for purpose of maintg. min. levels of D.O., tried on full scale on Flambeau R. Exptl. setup consisted of aerating station located downstream from sulfite mill at point where serious sag in D.O. occurred in stream during low summer flows. By use of Carborundum diffusers with total area of 319 sq.ft. set at depth of about 10' and fed by compressor capable of supplying 1550 cu.ft. of air per min. at 5 lb./sq.ft., possible to add to stream avg. of close to 1.5 tons of O per day at flow of 880 cu.ft./sec. This, together with immediate satisfaction of portion of B.O.D. of stream water, attributable to aeration, caused marked movement upstream of zone of recovery. Hence, process appears to be useful tool in accelerating recovery of pold. stream and shortening to considerable deg. distance of passage required for oxidation of waste and serves to prevent anaerobic conditions and attending nuisance.—*C.A.*

Representation of the Quality of Water in Flowing Water. G. JORDAN. Papier-Fabrikant (Ger.) **40:** 58, 66 ('42); Wass. u. Abwass. (Ger.) **40:** 113 ('42). Maint. of qual. of water as important in Germany as conservation of quant. of water and of water power. One of chief factors to be considered in evalg. qual. of flowing water is content of D.O., since upon this depends power of self-purif. of streams. Content of D.O. in river at particular place at regular intervals (Gütepegel) should be recorded and also content at several places along stream at one time (Güteprofil); results should be expressed graphically. Intervals of time between investigations at one place should not be longer than 1 mo. Various examples with diagrams given. To obtain picture of max. poln., investigations should be made at various points on river at time of least flow. Also necessary to make quarterly surveys in order to study seasonal changes. Knowledge of character and qual. of whole system of German watercourses can only be obtained by continuous surveys of this kind and these will be the chief task of the bureau of water research planned to cover the whole country.—*W.P.R.*

Control of Water Pollution. NORMAN J. HOWARD. Wtr. & Sew. (Can.) **85**:1:23 (Jan. '47). Control of water-borne disease tended, if anything, to aggravate water poln. situation, many claiming cheapest soln. of sewage problem disposal by diln. and adequate treatment of water before use. As result of poln., chem. cost of water purif. greatly increased, and taste and odor problems accentuated. State and provincial regulations forbid certain types of poln. but for some obscure reason they are seldom enforced, and prevention frequently falls upon municipalities which, because of their own sewage dischg., unable to act effectively. Increasing tendency on part of municipalities to require guarantee by new industries not to create local nuisance. In Toronto, new industries on waterfront must furnish details of effluent qual. before approval given. Poln. control activities in U.S., Canada and Great Britain reviewed. In U.S., consensus seems to be that fed. legis. impracticable because of variable conditions. —*R. E. Thompson.*

Water Supply of Amsterdam. J. KOOIJMANS. Water (Neth.) **31**:4 ('47). Studies on poln. and self-purif. of Amsterdam-Rhine Canal conducted during '39–'43 for purpose of detg. feasibility of using pold. canal water as source for potable supply led to following conclusions: (1) addn. of polder water had little effect on the chem. and bact. compn. of canal water, except that oxygen consumed values and color may increase; (2) industrial and domestic wastes detrimental to qual. of canal water; (3) eventually downstream qual. of water may be better than of Old Rhine. Chem. and bact. results show that (a) chloride content of water mixed with polder water is about 10 ppm. less than in river, (b) color increases by addn. of polder water; (c) oxygen consumed values decrease gradually in river, but increase when polder water added; effect of industrial and domestic waste slight; (d) suspended solids decrease; (e) D.O. decreases to low values on acct. of wastes, and gradually increases to original; (f) ammonia content increases on acct. of water, but rapidly decreases to lower value than in river; (g) org. nitrogen content did not improve; (h) total bacteria content improved; (i) coliform organisms decreased below river content. Self-purif. believed to be primarily result of low veloc. of water.—*Willem Rudolfs.*

Report of Commission on Studies of Urban Sanitation. M. Gaultier. Tech. Sanit. (Fr.), Nos. 11–12, 74–78 (Nov.–Dec. '46). Although separate sewage systems have some advantages, combined system recommended. Veloc. in sewers should be at least 0.30 m./sec. Prelim. treatment of sewage should consist of screening, grit removal or pre-settling. Primary treatment should comprise settling and digestion. Complete treatment, with exception of chem. coagulation, should consist of natural methods such as irrig. or fish ponds, or artificial means such as trickling filters or activated sludge, including digestion. In general, treatment should be sufficient (qual. and quant.) without interference with natural self-purif. processes in receiving waters.—*W. Rudolfs.*

Effect of Acid Wastes on Natural Purification of the Schuylkill River. Robert S. Chubb & Paul P. Merkel. Sew. Wks. J. **18**:692 (July '46). Natural stream, if used for sewage treatment, will purify itself by diln. if not overloaded. All domestic sewage contains organisms of biochemical decay which, when given sufficient oxygen, oxidize org. matter. These organisms, after consuming all available food, starved to death by stream. This, together with sedimentation, results in naturally purified stream. Graph presented of Schuylkill R., showing effect of acid waters on these organisms at various acid concns. and finally after water becomes alk. Favorable environment for decay organisms most important for sewage disposal.—*P.H.E.A.*

West Virginia Pushes Pollution Control. Anon. Eng. News-Rec. **138**:1025 (June 26, '47). Classification of quality of stream waters and zoning maps and rating studies serve as bases for treatment plant construction program.—*Ed.*

Preventing the Fouling of Cooling Waters Reduces Plant's Waste Disposal Costs. W. B. Hart. Petroleum Processing **1**:102 (Oct. '46). Article 10 in series on refinery waste disposal. Early and important step in planning effective waste disposal program is to adopt means for prevention, if possible, of contamn. of plant waters. Disposal of uncontamd. wastes relatively simple matter. Practical example of such prevention methods is installation of double discharge lines for water from tubular cooling equip., so that waste contamd. by leaking oil can be diverted to line leading to waste treating plant. Methods also given for protecting from contamn. waste water from coil cooler.—*Ed.*

Dairy Waste Disposal. H. A. Trebler & H. G. Harding. Chem. Eng. Progress. **43**: 255 ('47). Important features of dairy industry bearing on waste problems discussed. These include its great number of products, many sources of supply and ultimate customers, perishable nature of its products, seasonal character of milk supply, and exacting sanitary requirements. The trend is for more milk to be handled in larger, better-equipped factories. The trend toward higher prices for raw and processed dairy products makes by-product utilization, waste prevention, and waste saving increasingly attractive and necessary. Processes used in dairy plants discussed in relation to waste saving and waste prevention. Disposal of 5 types of liq. dairy wastes discussed. These include domestic waste, cooling waters, spoiled or excess products, drips, leaks and first rinses, and wash waters. Wide variations found in vol. of floor wastes and in B.O.D. losses in floor wastes and in vacuum-pan waters. Evaluation of these losses requires automatic sampling in direct proportion to the flow. Such a sampler described. Performance of dairy waste-disposal plant consisting of a high-rate, 2-stage concentric trickle filter with recirculated effluent and 2-stage split clarifier given for different loadings.—*C.A.*

Disposal of Slaughterhouse Waste. G. Brévot. Tech. Sanit. (Fr.) Nos. 11–12, 79–87 (Nov.–Dec. '46). Samples of waste from abattoirs at Villette contained 347 mil. aerobic and 19.4 mil. anaerobic organisms per ml., as compared with 27 mil. total organisms in sewage of Paris; org. suspended solids 5960–6830 ppm. and B.O.D. 595–788 ppm. Complete biol. treatment consisting of settling, chem. neutralization, trickling filters and digestion produces acceptable effluent. Final effluent must be disinfected. Superior Council of Public Health in France now recommends that municipalities work with specialists to assure, with maximum security, proper treatment of abattoir wastes.—*W. Rudolfs.*

CORROSION

Bituminous Coatings for the Protection of Iron and Steel Against Corrosion. ANON. Wtr. & Wtr. Eng. (Br.) **50**:206 (Apr. '47). Chem. Research Lab. of Dept. of Scientific and Industrial Research has published review of existing information on use of bituminous materials for protection of iron and steel against corrosion. Purpose of report is to stimulate use of coal tar and bitumen for protection of iron and steel against corrosion. In section on pigments those that have been commonly used in oil-type anti-corrosive paints classified and discussed. Properties of coatings discussed.—*H. E. Babbitt.*

Cathodic Protection of Steel Water Tanks Using Aluminum Anodes. L. P. SUBRABIN & R. B. MEARS. Am. Inst. Elec. Engrs. Preprint. (Jan. 27–31, '47); Abstr. Elec. Eng. **66**:1:89 (Jan. '47). Advantages of aluminum anodes for cathodic protection of steel water tanks over others include: (1) loss of weight per amp-hr. is, in agreement with theory, one-third that with iron; (2) they develop more uniform attack than steel or stainless steel; and (3) corrosion products, white or colorless, adhere to anodes, and do not discolor or contam. water. Anodes of several aluminum-base alloys have proved satisfactory. Anodes of aluminum-copper alloys (such as 17S-T or 24S-T) appear to be superior to anodes of unalloyed aluminum (2S) or to aluminum-zinc alloy anodes in installations where current supplied from external source.—*Corr.*

Electrical Protection of Steel Water Tanks Against Corrosion. R. J. SMITH. Eng. Cont. Rec. (Can.) **60**:5:92 (May '47). In '39, 208,000-gal. elevated tank, 150′ high and equipped for cathodic protection, installed in Perth, Ont. Rectifier delivers 4 amp. at 27 v. to stainless steel electrode, 18′ long and 1.25″ diam., suspended from tank roof. Electrode removed each fall as little corrosion occurs when water temp. 32–33°F. Interior of tank covered with gray film and rust absent. Electrode pitted and will be replaced by Mg rod. Less current required when Al or Mg electrodes employed and less metal consumed. Current of 4 ma. per sq.ft. may be required in case of water of low pH; protection against avg. Great Lakes water requires only 0.66. $CaCO_3$, if present in sufficient concn., deposited on metal, providing protection to metal periodically exposed between low and high water level. During first yr., deposit of rust, paint, etc., accumulates in bottom of tank. This should be removed and bottom covered with 1″ ground limestone. Cost of operation at Perth about $5 annually.—*R. E. Thompson.*

Selenium Rectifiers for Cathodic Protection. W. F. BONNER. Corrosion **2**:249 (Nov. '46). Selenium rectifiers described and shown; size and current capac. for heavy duty rectifiers tabulated; graphs show static resistance curve, voltage drop, effect of temp. on output voltage, eff. and operating time. Typical rectifier circuit connections and circuit data fabricated and drawn.—*Corr.*

New Stress Corrosion Control Methods. Oil Gas J., **45**:17:119 (Aug. 31, '46). Illinois Inst. of Technology has reported new stress corrosion control methods which include chem. soln. derived from coal tar which inhibits cracking even after it has started, and high temp. treatment of fabricated steel with hydrogen, which removes corrosion-stimulating nitrogen from metal surface.—*Ed.*

Tentative
Standard Specifications

for

THREADS FOR UNDERGROUND SERVICE LINE FITTINGS

These "Tentative Standard Specifications for Threads for Underground Service Line Fittings" are based upon a study of patterns for service line fittings now used widely in the water works field in North America. Should a purchaser wish to standardize his purchases in accordance with the dimensions given herein, he may do so by referring the manufacturer to this document (7T.1–7) and by naming the item or items he wishes to purchase.

Manufacturers are expressly advised that the term "A.W.W.A. Standard Threads for Service Line Fittings" can be applied only to fittings which conform to the dimensions herein.

American Water Works Association

Approved as Tentative by the Board of Directors of the A.W.W.A. on July 25, 1947

First Printing, October 1947

AMERICAN WATER WORKS ASSOCIATION

Incorporated

500 Fifth Avenue, New York 18, N. Y.

Foreword

The development of standards for threads for underground service line fittings was undertaken by the American Standards Association in 1929 and a subcommittee to develop such standards was appointed. This subcommittee developed proposed threads which were embodied in two drawings submitted by the subcommittee as the proposed standards. In 1932, the subcommittee reported that it believed its work had been completed and asked to be discharged. No action was taken by the American Standards Association on these proposed threads.

The need of standards for threads was recognized by the American Water Works Association and the appointment of a committee to recommend such standards was authorized in 1940. Although preliminary work was carried on by this committee, World War II made it advisable to stop such work until the summer of 1945. The membership of Committee 7T was then revised, with a member being appointed to represent virtually each of the A.W.W.A. Sections and W. H. Gourlie, Hartford, Conn., was appointed as technical consultant to the committee.

Through the co-operation of the manufacturers of these fittings, knowledge of current practices used for such threads was secured. Threads that represented current practice, as nearly as practicable, were set up for those fittings for which any substantial demand existed in the water works field.

No recommended standards have been set up for those threads which, on an annual production basis, represent only approximately 5 per cent or less of fittings called for by water works plants.

Also, no threads are included for service lines smaller than the ¾-in. size, as this size is the smallest approved by the Association.

The New England Water Works Association also appointed a committee on establishing standard threads for underground fittings and the committees of these two associations have co-operated closely in the work of setting up the recommended standards.

The setting up of standards has been limited to the threads, and the standards do not cover any other part of the underground service line fittings.

These standards have been submitted to the A.W.W.A. Board of Directors and were approved as Tentative on July 25, 1947.

Personnel of Committee

William W. Brush, *Chairman*

H. C. Cramer
E. T. Cranch
L. H. Daniel
M. S. Dutton
O. R. Elting
C. E. Fiveash
C. L. Fox
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T. J. Skinker
Marvin Turner
Paul Weir
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Representatives of New England Water Works Association

William W. Brush
Donald C. Calderwood

Threads for Underground Service Line Fittings

Section 1-1—General

The fittings covered by these specification are those in general use in the water works field for the installation of corporation stops in water mains and the service pipe extending from the main into the customer's premises up to the building stop.

Section 1-2—Description of Threads

Sec. 1-2.1—Drawings

2.1.1. All dimensions of threads shall be in accordance with the details given in Fig. 1–9, which form a part of these specifications.

2.1.2. The profiles shown in drawings are pictorial only, and producer's standards are to be furnished unless otherwise specified by the purchaser.

Sec. 1-2.2—Design Standards

2.2.1. The thread form shall be the same as that used on American National Taper Pipe Threads as approved by the American Standards Association, December 1945, and designated as ASA-B2.1-1945.

2.2.2. All starting threads shall be chamfered in accordance with the manufacturer's standard practice.

2.2.3. Thread forms for all straight threads in copper and lead services (Fig. 2–8) shall be in accordance with American National standards, with tolerances approximating Class 2, and allowances as indicated.

2.2.4. Wherever tapered iron pipe threads are called for, they shall conform to American Standard ASA-B2.1-1945.

2.2.5. A number of other fittings are used in underground water service, such as adapters for changing from lead service to copper service, copper service to iron pipe, and so on. Such fittings shall be furnished with threads made in accordance with the standard established for each service. No separate drawings of these threads are included in this standard.

2.2.6. If the purchaser specifies a wood screw thread on the inlet end of the corporation stop, it shall be made in accordance with the producer's standards.

2.2.7. On corporation stops, any plain extension at the inlet end shall be in addition to the thread length L as shown on Fig. 1.

2.2.8. The standard corporation stop thread shown in Fig. 1 is the one most extensively used on the inlet end of the corporation stop in American water works practice.*

2.2.9. In gaging A.W.W.A. standard thread, the thread is within tolerances when the gaging face is within one turn of being flush with the end of the thread.

2.2.10. If the purchaser specifies that the corporation stop furnished shall be finished with a tapered iron pipe thread, this thread shall conform to ASA-B2.1-1945 (as stated in Sec. 1-2.2.4 of these specifications), with the extra thread added at the large end of the corporation stop.

* This thread is commonly known to the trade as the Mueller Thread.

TABLE 1

Standard Corporation Stop Thread

Nominal Size	Threads per inch	Taper per foot	Diameters at Small End			Length L (min.)
			Major	Pitch	Minor	
in.		*in.*	*in.*	*in.*	*in.*	*in.*
$\frac{3}{4}$	14	$1\frac{3}{4}$	1.104	1.047	0.990	$1\frac{1}{8}$
1	12	$1\frac{3}{4}$	1.332	1.265	1.198	$1\frac{3}{16}$
$1\frac{1}{4}$	$11\frac{1}{2}$	1	1.728	1.658	1.588	$1\frac{3}{8}$
$1\frac{1}{2}$	$11\frac{1}{2}$	1	2.004	1.934	1.864	$1\frac{1}{2}$
2	$11\frac{1}{2}$	1	2.577	2.507	2.437	$1\frac{17}{32}$

This thread is for use on the inlet end.

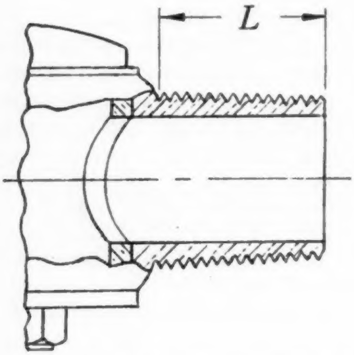

FIG. 1. Standard Corporation Stop Thread

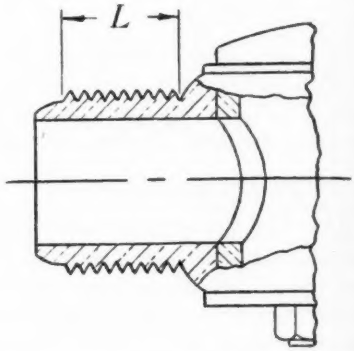

FIG. 2. Fitting Thread for Use With Flared Copper Service Tubes, Type K

TABLE 2

Fitting Thread for Use With Flared Copper Service Tubes, Type K

Nominal Size	Threads per inch	Major		Pitch		Minor Diam. (max.)	Length L (min.)
		Diam.	Tol.	Diam.	Tol.		
in.		*in.*	*in.*	*in.*	*in.*	*in.*	*in.*
$\frac{3}{4}$	14	1.259	−0.010	1.213	−0.006	1.171	$\frac{5}{8}$
1	$11\frac{1}{2}$	1.593	−0.015	1.536	−0.008	1.486	$\frac{3}{4}$
$1\frac{1}{4}$	$11\frac{1}{2}$	2.055	−0.015	1.998	−0.008	1.948	1
$1\frac{1}{2}$	$11\frac{1}{2}$	2.465	−0.015	2.408	−0.008	2.358	$1\frac{1}{16}$
2	$11\frac{1}{2}$	3.185	−0.015	3.128	−0.008	3.078	$1\frac{5}{16}$

External thread is designed for the external coupling threads of corporation stops, curb stops and adapters for use with flared copper service tubes, Type K.

Internal driving thread shall be provided in copper service corporation stops only when so specified. Such threads shall conform to Fig. 8.

TABLE 3

Coupling Nut for Use With Flared Copper Service Tubes, Type K

Nominal Size	Threads per inch	Major Diam. (min.)	Pitch		Minor		Length *L* (min.)
			Diam.	Tol.	Diam.	Tol.	
in.		*in.*	*in.*	*in.*	*in.*	*in.*	*in.*
$\frac{3}{4}$	14	1.266	1.220	+0.006	1.189	+0.008	$\frac{5}{8}$
1	$11\frac{1}{2}$	1.603	1.546	+0.008	1.509	+0.010	$\frac{3}{4}$
$1\frac{1}{4}$	$11\frac{1}{2}$	2.065	2.008	+0.008	1.971	+0.010	1
$1\frac{1}{2}$	$11\frac{1}{2}$	2.475	2.418	+0.008	2.381	+0.010	$1\frac{1}{16}$
2	$11\frac{1}{2}$	3.195	3.138	+0.008	3.101	+0.010	$1\frac{5}{16}$

This thread is designed for all internal threads in fittings for use with flared copper service tubes, Type K.

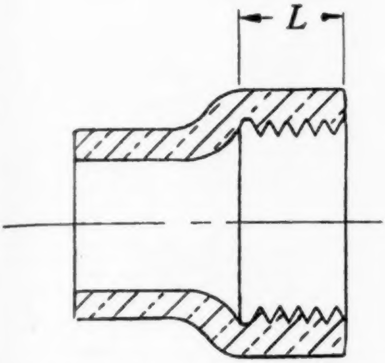

FIG. 3. Coupling Nut for Use With Flared Copper Service Tubes, Type K

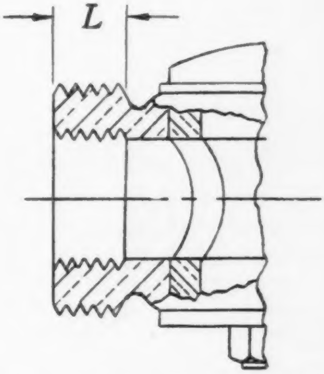

FIG. 4. Fitting Thread for Use With Extra Strong Lead Flanged Pipe

TABLE 4

Fitting Thread for Use With Extra Strong Lead Flanged Pipe

Nominal Size	Threads per inch	Major		Pitch		Minor Diam. (max.)	Length *L* (min.)
		Diam.	Tol.	Diam.	Tol.		
in.		*in.*	*in.*	*in.*	*in.*	*in.*	*in.*
$\frac{3}{4}$	12	1.843	−0.015	1.789	−0.008	1.741	$\frac{1}{2}$
1	12	2.158	−0.015	2.104	−0.008	2.056	$\frac{9}{16}$
$1\frac{1}{4}$	10	2.526	−0.015	2.461	−0.011	2.403	$\frac{5}{8}$
$1\frac{1}{2}$	10	2.794	−0.015	2.729	−0.011	2.671	$\frac{11}{16}$
2	10	3.357	−0.015	3.292	−0.011	3.234	$\frac{3}{4}$

External thread is designed for corporation stops, curb stops, and fittings used with extra strong lead flanged pipe.

Internal thread for driving is for corporation stops only and shall conform to Fig. 8.

TABLE 5

Coupling Nut for Use With Extra Strong Lead Flanged Pipe

Nominal Size	Threads per inch	Major Diam. (min.)	Pitch		Minor		Length L (min.)
			Diam.	Tol.	Diam.	Tol.	
in.		*in.*	*in.*	*in.*	*in.*	*in.*	*in.*
3/4	12	1.853	1.799	+0.008	1.763	+0.009	11/16
1	12	2.168	2.114	+0.008	2.078	+0.009	13/16
1 1/4	10	2.536	2.471	+0.011	2.428	+0.010	15/16
1 1/2	10	2.804	2.739	+0.011	2.696	+0.010	1
2	10	3.367	3.302	+0.011	3.259	+0.010	1 1/16

This thread is designed for coupling nuts used with extra strong lead flanged pipe.

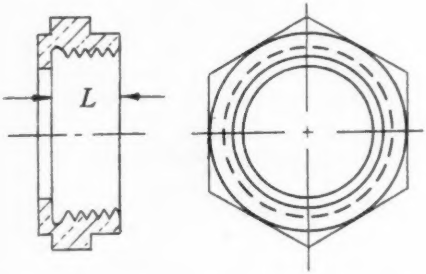

Fig. 5. Coupling Nut for Use With Extra Strong Lead Flanged Pipe

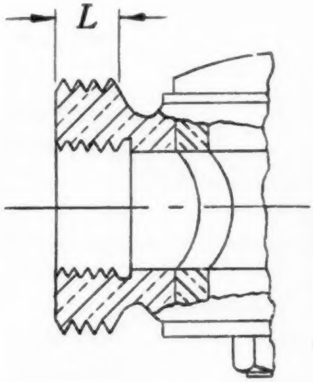

Fig. 6. Fitting Thread for Use With Double Extra Strong Lead Flanged Pipe

TABLE 6

Fitting Thread for Use With Double Extra Strong Lead Flanged Pipe

Nominal Size	Threads per inch	Major		Pitch		Minor Diam. (max.)	Length L (min.)
		Diam.	Tol.	Diam.	Tol.		
in.		*in.*	*in.*	*in.*	*in.*	*in.*	*in.*
3/4	12	2.030	−0.015	1.976	−0.008	1.928	1/2
1	12	2.323	−0.015	2.269	−0.008	2.221	9/16
1 1/4	10	2.639	−0.015	2.575	−0.011	2.516	5/8
1 1/2	10	3.070	−0.015	3.006	−0.011	2.947	11/16
2	10	3.556	−0.015	3.492	−0.011	3.433	3/4

External thread is designed for corporation stops, curb stops and fittings used with double extra strong lead flanged pipe.

Internal thread for driving is for corporation stops only and shall conform to Fig. 8.

TABLE 7

Coupling Nut for Use With Double Extra Strong Lead Flanged Pipe

Nominal Size	Threads per inch	Major Diam. (min.)	Pitch		Minor		Length L (min.)
			Diam.	Tol.	Diam.	Tol.	
in.		*in.*	*in.*	*in.*	*in.*	*in.*	*in.*
$\frac{3}{4}$	12	2.040	1.986	+0.008	1.950	+0.009	$\frac{11}{16}$
1	12	2.333	2.279	+0.008	2.243	+0.009	$\frac{13}{16}$
$1\frac{1}{4}$	10	2.649	2.585	+0.011	2.541	+0.010	$\frac{15}{16}$
$1\frac{1}{2}$	10	3.080	3.016	+0.011	2.972	+0.010	1
2	10	3.566	3.502	+0.011	3.458	+0.010	$1\frac{1}{16}$

This thread is designed for coupling nuts used with double extra strong lead flanged pipe.

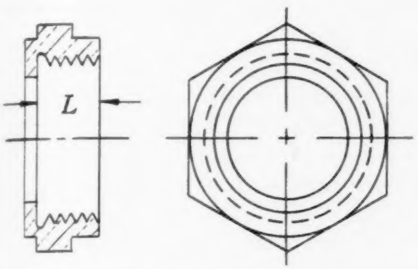

FIG. 7. Coupling Nut for Use With Double Extra Strong Lead Flanged Pipe

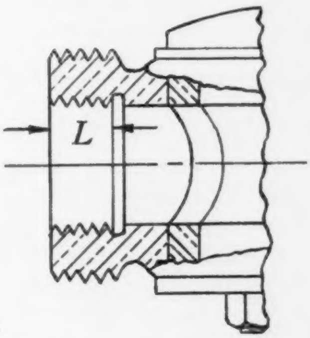

FIG. 8. Internal Driving Thread for Corporation Stops

TABLE 8

Internal Driving Thread for Corporation Stops

Nominal Size	Threads per inch	Major Diam. (min.)	Pitch		Minor		Length L (min.)
			Diam.	Tol.	Diam.	Tol.	
in.		*in.*	*in.*	*in.*	*in.*	*in.*	*in.*
$\frac{3}{4}$	12	0.855	0.801	+0.006	0.765	+0.009	$\frac{5}{8}$
1	12	1.089	1.035	+0.006	0.999	+0.009	$\frac{11}{16}$
$1\frac{1}{4}$	10	1.374	1.309	+0.010	1.266	+0.011	$\frac{13}{16}$
$1\frac{1}{2}$	8	1.666	1.585	+0.010	1.531	+0.014	1
2	8	2.165	2.084	+0.010	2.030	+0.014	$1\frac{1}{8}$

This internal driving thread is designed for all types of corporation stops.

TABLE 9

Tapered Iron Pipe Thread for Outlet End of Corporation Stops

Nominal Size	Pipe Thread	
	Size	Threads per inch
in.	*in*	
¾	1	11½ NPT
1	1¼	11½ NPT
1¼	1½	11½ NPT
1½	2	11½ NPT
2	2½	8 NPT

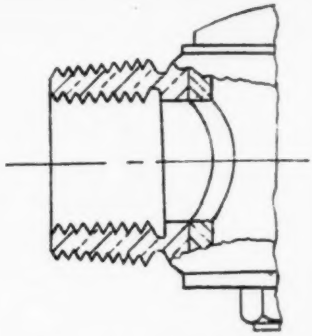

FIG. 9. Tapered Iron Pipe Thread for Outlet End of Corporation Stops

American National Taper Pipe Thread one size larger than nominal is used on outlet end of corporation stops when connection is to iron pipe service.

Internal thread is for driving and shall conform to Fig. 8.

Erratum

In the paper "Adjusting Rate Structures to Rising Cost Levels," by Louis R. Howson (Vol. 39, p. 819, September 1947 JOURNAL), the amount given for the tonnage of water produced annually was in error, and should have read 12,000,000,000 instead of 1,800,000,000 tons. The error affects Fig. 1 and 3 of the paper (pp. 820, 821) and paragraphs three and five (pp. 819, 820), which should be corrected to read as follows (corrected data in italics):

> As a commodity, water is most important. Figure 1 indicates its importance as measured in the annual tonnage produced, compared with coal, steel, wheat and cement. The tonnage of water delivered to American distribution systems in a year is *17* times the tonnage of all the coal mined in the United States. It is approximately *140* times the tonnage produced by all the steel mills in the country in their banner year. It is *400* times the tonnage of wheat grown in a billion-bushel crop year. . . .
>
> As a transportation system, the water works of the United States transport over *12,000,000,000* tons of water per year, or *four times* as much tonnage as all the railroads of the United States. The average revenue from this transportation service by the water works (Fig. 3), is approximately *0.05¢* per ton-mile, in contrast to the 0.95¢ charge per ton-mile of American railroad freight transportation. The water works revenue also includes the cost of the commodity transported, whereas the railroad revenue does not.

It will be noted that the changes increase the comparative importance of the water works industry to all others, and decrease the relative cost.